INFLUENCE OF NO-TILL AND CONVENTIONAL TILLAGE ON INSECT PESTS AND SOIL INHABITING PREDATOR POPULATIONS IN FLORIDA SOYBEAN AND CORN CROPPING SYSTEMS

By

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To my parents,

sisters, and

brothers

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Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

INFLUENCE OF NO-TILL AND CONVENTIONAL TILLAGE ON INSECT PESTS AND SOIL INHABITING PREDATOR POPULATIONS IN FLORIDA SOYBEAN AND CORN CROPPING SYSTEMS

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The effect of no-tillage cropping on insect pests and ground-dwelling arthropod predators was assessed in soybean and corn crop systems in Levy and Alachua Counties, Florida, from April to November 1978 and 1979. No tillage and conventional tillage, with in-row subsoil as a subtreatment for both, were compared in rye (*Secale cereale* L.), corn (*Zea mays* L.), oat (*Avena sativa* L.), wheat (*Triticum aestivum* L.) and vetch (*Vicia villosa* Roth) stubble or mulch.

Damage to soybeans [*Glycine max* (L.) Merrill] and corn was determined weekly by visual observations. The sweep net and plant shaking methods were used to monitor pest populations in soybeans. The activity of ground-dwelling arthropods (pests and predators) was monitored in both corn and soybean systems using pitfall traps.

In soybeans, above-ground insect pests and the lesser cornstalk borer, _Elasmopalpus lignosellus_ (Zeller), were generally unaffected by the no-tillage farming. No tillage did not significantly affect damage due to _Spodoptera frugiperda_ (J. E. Smith) and _Heliothis zea_ (Boddie) or populations of _Conoderus_ spp. on corn. The results also indicated that no tillage greatly increased populations of the granulate cutworm, _Feltia subterranea_ (Fab.), without affecting cutworm damage to corn seedlings. No tillage, however, significantly reduced lesser cornstalk borer damage in corn.

Populations of ground-dwelling spiders were not affected by the no-tillage practice, and the effect of this practice on the dermapteran _Labidura riparia_ (Pallas) was not consistent. In soybeans no tillage significantly increased the activity of carabid beetles whereas in corn most carabids were collected from conventional tillage treatments.

Yields of soybeans were reduced in the no-tillage systems as compared to the conventional tillage. Corn yields, however, were not affected by the no-tillage practice.

INTRODUCTION

No tillage or zero tillage is defined as the agronomic practice that consists of planting crop seeds in sod or crop residues in a previously unprepared soil (Young, 1970; Triplett and Van Doren, 1977). The soil is not disturbed except for a narrow (5-7 cm wide) slit made by the planter and in which the seeds are planted.

In the conventional tillage procedure a number (up to ten) of trips across the field are made for soil preparation and weed control. According to Young (1970), any practice that reduces the number of these trips (e.g. plow and plant, chiseling and plant) is a minimum or reduced tillage, an operation distinctly different from the no tillage. Some workers, however, consider the no-tillage practice as a case of minimum tillage, and use the term "conservation tillage" to include both the minimum (reduced) and no tillage. The systems studied in this work are considered as no-tillage systems, and the terms no-till and no tillage are used interchangeably.

No-tillage cropping has numerous advantages over the conventional tillage practice. Nontilled soils retain moisture longer than tilled fields (Moody et al., 1963; Triplett et al., 1968). Plant residues in no-tillage systems prevent or

reduce soil loss by water and wind erosion (Triplett et al., 1978). Crop yields obtained from no-tillage systems are reported to be higher than, or at least equal to, those from conventionally tilled fields when no tillage is practiced on well drained soils and weed control is adequate (Rask et al., 1967; Triplett and Van Doren, 1977; Lal, 1979). A great saving in energy and labor also results from no tillage. Rask et al., (1967) estimated that production costs can be reduced by as much as 75% in no-tillage systems due to the elimination of tillage operations.

Farmers are increasingly adopting the no-tillage practice as an alternative to the conventional tillage for crop production (Blevins et al., 1971). It is predicted that over 90% of the U. S. crop acreage will be grown under reduced tillage by the year 2010; at least half of this acreage will be under no-tillage farming (Triplett and Van Doren, 1977).

Fear of pest problems is one of the main objections to the adoption of the no-tillage practice by many growers. It is believed that, since the soil is not disturbed and crop residues are left on the soil surface in no-tillage systems, pest problems will be more severe in these systems than in conventionally tilled fields. Musick (1970a, b) reported that soil insects such as wireworms, seed corn maggots and cutworms cause considerable damage to no-tillage corn (*Zea mays* L.) in Ohio. Some crop diseases also cause more serious damage to no-tillage crops than to crops planted in conventionally tilled fields (Burns, 1973).

Doupnik et al. (1975) and All and Gallaher (1977) observed that the conditions created in untilled fields were not favorable to all pest species, and that no tillage may have detrimental effects on some pest organisms. The lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller), caused less damage in no-tillage than in conventional tillage corn (All and Gallaher, 1977), and stalk rot incidence of grain sorghum, [*Sorghum bicolor* (L.) Moenck], was higher in conventionally tilled than in nontilled blocks in Nebraska (Doupnik et al., 1975).

Because of the increasing adoption of no tillage as a crop production procedure, detailed studies are needed to better understand the biology and behavior of pest species, and to assess the importance of pest problems in no-tillage systems. Experiments were conducted in Alachua and Levy counties, Florida, in order to discern the influence of no tillage on the most important insect pests of corn and soybean [*Glycine max* (L.) Merrill] ecosystems. Data were also collected to determine the effects on soil-inhabiting arthropod predators.

CHAPTER I

LITERATURE REVIEW

No-Tillage Systems

Advantages and Disadvantages of No Tillage

Disadvantages. Several disadvantages are associated with the no-tillage practice. Musick (1970b) reported slower corn seed germination due to lower soil temperatures in untilled fields. Early crop growth is also reported to be depressed temporarily in no-tillage systems (Moody et al., 1963). Late in the growing season, however, crop growth in no tillage is faster than in tilled fields because of high soil moisture associated with plant residues.

Plant density was observed to be generally lower in no-tillage fields than in conventionally tilled fields. This is due in part to the fact that some seeds do not get into the furrow and are eaten by birds and rodents. Growers in Illinois consider rodents to be important pests of crops in no-till culture (Herzog, personal communication, 1980).

Crop yields from no tillage may be lower than those obtained from conventional tillage when no-tillage systems are established on some types of soils. Griffith et al.

(1973) observed that on poorly drained fine-structured soils, no-tillage corn gave lower yields than did the conventional tillage corn.

Musick (1970a, b) reported that conditions created in no-tillage systems (crop residues, high soil moisture and low temperatures) are conducive to pest activity. Pest problems are believed to be the principal disadvantage farmers associate to the no-tillage practice. Several pest organisms overwinter in plant residues, and readily attack the new crop when conditions become favorable. In conventional soil tillage such pests are usually controlled by physical destruction, exposure to unfavorable weather, and natural enemies.

Advantages. Among the numerous advantages of the no-tillage practice, the more important are those associated with protection of soil from erosion, reduction in energy input required for crop production, as well as increased crop growth and yields due to higher soil moisture. Moody et al. (1963) and Jones et al. (1968) found that soil moisture was higher in the no-tillage than in the conventional tillage corn, and that this higher soil moisture significantly increased corn growth and yields. Mulched corn was 64 cm taller at tasseling and produced 47 kg/ha more grain than conventional tillage corn (Moody et al., 1963). Triplett et al. (1968) also observed a significant

increase of plant height as the amount of surface cover increased in nontilled corn fields.

Runoff becomes a very important factor in the no tillage because of large quantities of herbicides used in these systems. Such runoff may increase the amount of soluble chemicals in streams (Holt et al., 1973). According to Unger and Phillips (1973), plant residues on untilled soil reduce evaporation, runoff, and prevent crusting of the soil surface.

The subject of soil erosion by water and wind has been treated by a number of authors including Wischmeier (1973), Woodruff and Siddoway (1973), and Triplett et al. (1978). Soil erosion results in a tremendous loss of topsoils in croplands. No-tillage practice greatly reduces soil erosion because of the mulch that remains on the soil surface. Triplett and Van Doren (1977) in Ohio observed that a 12.70 cm rainfall caused losses of up to 45 tons of soil/ha from conventional tillage corn fields with slopes of 6-8% whereas a 20% slope watershed with no-tillage corn had a loss of less than 112 kg/ha. Reduced and no-tillage systems can decrease erosion potential as much as 50-fold (Triplett et al., 1978).

No-tillage cropping procedure is particularly important for crop production on lands with slopes so steep that conventional tillage would cause unacceptable damage due to erosion. This is especially true in tropical regions where soils are highly erodible and rainfall intensities are high (Curfs, 1976). Curfs (1976) recommended no-tillage and

reduced tillage systems as an alternative for shifting cultivation widely practiced in the tropics. The traditional system of shifting cultivation protects the soil from erosion, but, according to Lal (1973), it supports only one person on 15 ha of land and continuous cropping under this system may ruin the soils.

The main advantage of the no tillage is undoubtedly the tremendous reduction in crop production costs that result from reduced machinery use and associated reduction in fuel consumption. A great saving in time and labor also results from the no-tillage practice. The economics of the no tillage is reviewed in the next section.

Economics of No-Tillage Systems

The economic aspect is the most important factor considered by the farmers in accepting the "new" crop production practice. As discussed by Shipley and Osborn (1973), conservation tillage must produce a net return equal to, or greater than, that obtained with the conventional tillage if the farmer is to switch from the conventional to the conservation tillage.

Rask et al. (1967) obtained a reduction of as much as 75% in production costs and a saving in time of 70-80% in no-tillage corn. Doster (1976) calculated production costs in conventional and conservation tillage systems in Indiana and found that no tillage with coulter disc was the cheapest,

and spring plowing the most expensive system for corn production. In one study (Doster, 1976) total costs (machinery, herbicides, and part-time costs) were $62.49, $72.07, and $48.05 in conventional fall plow, conventional spring plow, and no tillage with coulter disc, respectively. The authors also reported that herbicides were the most expensive item in the no-tillage farming.

A tremendous saving in fuel results from reduced machinery use in no tillage. Triplett and Van Doren (1977) pointed out that fuel consumption in untilled corn was reduced by as much as two-thirds of the amount consumed in the conventional tillage.

Reports by various workers (Rask et al., 1967; Jones et al., 1968; Triplett and Van Doren, 1977) showed that yields from no tillage were 10-39% higher than those from the conventional tillage. Higher yields combined with reduced machinery costs and saving in labor results in significantly higher net profits.

Young (1970) reported that net money returns from no-tillage farming were usually greater than with conventional tillage systems. Doster (1976) evaluated net returns for 243 ha of corn continuously grown in various tillage systems in Indiana. He observed that spring plowing practiced on Tracy silt loam yielded net returns of $76,000 while no tillage with coulter gave a net return of $81,500. On Runnymede loam, however, spring plowing and no-tillage coulter yielded $94,000 and $68,000, respectively for the 243 ha.

Pest Problems in No-Tillage Agroecosystems

Weeds in no tillage. An effective chemical weed control is a prerequisite to acceptable crop yields from the no tillage. In a seven-year study, Triplett and Lytle (1972) confirmed weed control to be the dominant factor limiting high crop yields. Griffith et al. (1973) showed that crop yields in no-plow systems may be lower than those from conventionally plowed fields if weed control is not adequate.

Weed control is no longer a serious problem in no-plow agroecosystems because of the development of effective herbicides. Several herbicides such as atrazine (see Appendix A for chemical names), paraquat, simazine, against grasses, and 2,4-D, etc., against broad-leaf weeds, have achieved satisfactory weed control in the no-tillage cropping procedure (Triplett, 1966; Triplett and Lytle, 1972).

Some problems related to weed control have developed in no-tillage crop production due to the lack of soil tillage and cultivation. Triplett and Lytle (1972) observed that annual weed populations shifted with different herbicides, when corn was continuously grown on no tillage for seven years. Atrazine and simazine controlled most of the weeds, but the fall panicum (*Panicum dichotomiflorum* Michx.) became a major annual weed where those two herbicides were used. The authors also found that hemp dogbane (*Apocynum cannabinum* L.) became a serious problem after several years of continuous corn production under no-tillage farming (Triplett and Lytle, 1972).

Wiese and Staniforth (1973) also reported that hemp dogbane spreads rapidly where the soil is not tilled.

Peters (1972) and Triplett and Lytle (1972) found that several perennial weed species were tolerant to herbicides. The common milkweed (Asclepias syriaca L.), horsenettle (Solanum carolinense L.), groundcherry (Physalis sp.), and the tall ironweed (Vernonia altissima Nutt.), are some of those weed species that survive in untilled fields. Lewis (1970) concluded that bermudagrass [Cynodon dactylon (L.) Pers.], johnsongrass [Sorghum halepense (L.) Pers.], and dallisgrass (Paspalum dilatatum Poir) cannot be effectively controlled chemically in no-tillage systems.

Some of the herbicide applied in untilled, mulched fields may be intercepted by crop residues; this reduces the amount of the chemical that reaches the target species (Triplett, 1976).

Crop diseases in no tillage. The problem of crop diseases in conservation tillage has been investigated by several workers including Burns (1973), Roane et al. (1974), Yarham (1975), and White and Janney (1978). A large number of plant pathogens inhabit or overwinter in crop residues and the soil. They readily move to the new crop as soon as weather conditions become favorable and susceptible host plants are available (Graham, 1953; Kennedy, 1969; Daft and Leben, 1973).

The lack of soil disturbance as well as the presence of decaying plant material left on the ground may increase the incidence of the diseases in no-tillage fields. Boosalis and Doupnik (1976) reported that fungus and bacterial diseases are the principal diseases associated with reduced tillage.

Ledingham et al. (1960) compared root rot incidence in wheat (_Triticum aestivum_ L.) grown in two tillage systems, a surface tillage that left a trash cover on the ground, and a moldboard-plowed stubble soil. The authors found that plowing was effective in reducing disease incidence during the seedling stages, but no significant difference was observed in infection levels as the crop matured.

Burns (1973) reported that the brown spot of corn caused by _Physoderma maydis_, a fungus that overwinters in infested corn debris, was more severe in reduced tillage plots than in conventionally tilled plots. Burns (1973) also reported that both the virus that causes wheat streak mosaic and the mites that transmit it overwinter on living wheat and perennial grasses, and that the greatest damage to wheat was observed in fields planted close to wheat stubble.

Several reports have indicated that crop plants on no-tillage soil are not affected differently from those on conventionally plowed land. In some instances, conservation tillage practices were even reported to reduce disease incidence.

Keyworth (1942) in England demonstrated that soil cultivation was the major factor for the spreading of the

Verticillium wilt within and from one garden to another. McCalla (1967) reported that tillage operations transport various kinds of soil microorganisms from one site to another.

In Oregon, Hall (1959) studied the effects of fertilization dates and plowing methods on the incidence of root rot of Burt wheat caused by *Fusarium* sp. The author concluded that stubble mulch did not increase the disease incidence as compared to plowed plots. In a similar study in Iowa, Parker and Burrows (1959) reached the same conclusion about the incidence of corn root and stalk rot: disease incidence was lowest in those tillage systems where corn stalk residue was left on the soil surface, and where no or low levels of N were applied.

Brooks and Dawson (1968) drilled winter wheat directly into rye (*Secale cereale* L.) stubble to investigate the effects of this cultural practice on take-all (*Ophiobolus graminis* Sacc.) and eyespot (*Cercosporella herpotrichoides* Fron.). No differences in infection levels were found between plowed and unplowed plots before the first three months. Three months after planting, however, disease incidence increased greatly in plowed plots. The authors found that plants in untilled plots were infested earlier than those in conventional tillage plots, but that the rate of spread of the fungus was restricted by adverse soil conditions in no-tillage plots.

Doupnik et al. (1975) believed that factors such as increased water conservation, reduced soil temperature

fluctuations, and better chemical weed control contributed to the reduction of the stalk rot incidence observed in no-tillage grain sorghum seeded in wheat stubble in Nebraska.

After studying crop diseases in no-tillage cereals, Yarham (1975) concluded that "increase in disease levels has not been sufficient to depress seriously the yields of the nonplowed plots. At the moment, it does not appear likely that cultivation-disease interaction will substantially influence the success or failure of nonplow techniques" (p. 247).

Effects of no tillage on insect pests. Soil plowing has been recommended for many years as an effective control measure against several insect pests (Barber and Dicke, 1937; Adkisson et al., 1960; Hardwick, 1965; and Frohlich and Rodewald, 1970). This practice reduces insect pest populations through physical destruction, exposure to natural enemies, and detrimental weather conditions.

Barber and Dicke (1937) compared the emergence of the corn earworm [(*Heliothis zea* (Boddie)] moths from hibernation in various soil types and tillage systems in Virginia and Georgia. Fall and spring plowing and fall disking significantly reduced pest emergence as compared to the uncultivated soil. Spring plowing, however, was less effective than fall plowing or fall disking in reducing the corn earworm emergence. The authors also found that soil type affected the effectiveness of cultivation as control measure. Plowing was more effective in sandy loam soil than in red clay soil.

In the lower Rio Grande Valley of Texas, Fife and Graham (1966) obtained a 100% control of both H. zea and the tobacco budworm [Heliothis virescens (Fab.)] after listing, disking and relisting the land in combination with a preplanting irrigation. Listing the land alone reduced the emergence of H. zea moths from pupae by about 55% in a pepper field.

When the larvae of these two species are fully grown, they leave their host plants and burrow into the soil to pupate in pupal cells. According to Fife and Graham (1966), these pupal cells are located at 1.27-15.24 cm below, and their tunnels extend near, the soil surface. Cultivation destroys most of the cells and tunnels in addition to the physical pupal destruction.

Destruction of stalk and other plant parts is also used to regulate insect pest populations (Metcalf, 1909). Several insect pest species remain in crop residues between cropping seasons and attack the new crop as soon as it is available. Adeyemi (1969) showed that stem borers such as Busseola fusca (Fuller), Sesamia calamistis Hamps., etc., can survive in corn stalks from season to season in large enough numbers to initiate borer infestations of the succeeding crop. An average borer population of 27 per 100 stems examined was found in stubble after the first-season corn harvest.

Fenton and Owen (1953), Noble (1955), and Fife et al. (1957) reported burial of cotton (Gossypium spp.) residues

through plowing to be an effective method in controlling the pink bollworm, Pectinophora gossypiella (Saund.), in Texas cotton fields. Adkisson et al. (1960) found that burying cotton material during the winter killed 76 to 83% of the pink bollworm larvae, and that an average of 51.6% of the larvae survived the winter in infested cotton left on the ground.

Conditions created in no-tillage systems are reported to be conducive to insect activity (Musick, 1970b). Insect problems in the no-tillage cropping are, therefore, believed to be more severe than in the conventionally tilled fields.

Musick (1970a, b) and Musick and Petty (1974) stated that soil insects constitute the most serious threat to no-tillage corn production. The seed corn maggot, Hylemya platura (Meigen), is active at low temperatures and female flies oviposit in soil where surface trash and decaying plant matter are abundant. This pest is believed likely to cause severe damage to no-tillage crops. Other soil insects such as seed corn beetles, wireworms, cutworms, white grubs, and corn rootworms are also a more serious threat in no tillage than in conventional tillage corn production.

In Ohio in 1969 (Musick, 1970b), soil insects, mostly wireworms and seed corn maggots, reduced the stand by 20-25% more in the no-tillage portions of some fields than in the conventionally tilled portions. Other no-till fields

had up to more than 90% stand reduction. Musick and Collins (1971) documented that tillage system may influence the oviposition pattern of some insects. Females of the northern corn rootworm, Diabrotica longicornis Say, laid more eggs in no-till corn than in corn planted on conventionally plowed land.

Some above-ground insects are also expected to cause higher damage levels in untilled fields than in crops produced by the conventional tillage system (Gregory and Musick, 1976). The European corn borer (ECB), Ostrinia nubilalis (Hubner), overwinters as mature larvae in corn stalks, and populations of the ECB have been regulated by clean plowing. Damage due to this pest will be more severe in no-tillage corn than in plowed corn (Gregory and Musick, 1976). Musick (1973) and Musick and Suttle (1973) observed that the armyworm [Pseudaletia unipuncta (Haworth)] females preferentially oviposited in grassy areas, and that the incidence of armyworm damage was higher in no-tillage corn, especially when corn was seeded directly in grass or fall-planted wheat.

The blackfaced leafhopper, Graminella nigrifrons (Forbes), transmits two virus diseases to corn, the maize chlorotic dwarf (MCD) and maize dwarf mosaic (MDM). In a study involving no-tillage cropping, carbofuran and hybrid resistance to the diseases, All et al. (1977) found a greater leafhopper population in no till than in the conventional tillage, but no significant difference was observed in yield loss due to MCD infection. Incidence of MDM was generally very low.

As stated by Musick (1970a), not all insect pests will cause serious problems in no-till culture. Some serious pests may become less important while the status of some secondary pests may be changed to that of destructive pests.

In Georgia, All and Gallaher (1977) and All et al. (1979) reported that infestations by the lesser cornstalk borer (LCB) were greatly reduced in no-tillage corn. All and Gallaher (1977) first speculated that higher soil moisture, lower soil temperatures and greater soil compaction near the surface in no-till systems were detrimental to the optimum development and survival of E. lignosellus larvae and, therefore, responsible for the lower infestations observed in these systems.

Cheshire et al. (1977) and Cheshire and All (1978), in a detailed study, however, found that crop residues left on the ground might be the most important factor in reducing the LCB damage in no-tillage corn. Crop residues "may inhibit LCB feeding by disrupting location of host plants by smell or by mechanically shielding the host plant" (Cheshire and All, 1978, p. 12). The facultative saprophagous larvae consequently feed on crop stubble instead of attacking crop plants.

All et al. (1979) also found that a combination of control measures applied against E. lignosellus were more effective in no-till blocks than in the conventional tillage. Early planting, preplanting weed control, and applications of carbofuran resulted in a better LCB control in untilled fields than in those conventionally tilled.

Rivers et al. (1977) planted corn into a sod field infested with white grubs, Phyllophaga anxia (LeConte), to investigate the influence of tillage systems on grub populations. After two years of observations, the authors found that the populations of white grubs were significantly higher in the soil around plants in the conventional tillage than in the no-tillage plots. They believed that this phenomenon was due to the fact that grubs preferred to feed on the grass left between crop rows in the no tillage.

In Indiana, Sloderbeck and Edwards (1979) reported that changes in row width did not significantly affect population levels of the Mexican bean beetle, Epilachna varivestis Mulsant, and redlegged grasshopper, Melanoplus femurrubrum (De Geer), but that tilled soybeans harbored significantly more larval and adult Mexican bean beetles than no-till soybeans. No till in combination with double cropping, however, increased population levels of the redlegged grasshopper as it continuously provided a suitable habitat for the grasshopper.

Soybean and Corn Insect Pests in Florida

Soybean Insects

Three-cornered alfalfa hopper. The biology and description of adults and nymphs of the three-cornered alfalfa hopper, *Spissistilus festinus* (Say), may be found in Turnipseed (1973). Damage to soybeans is caused by adults and nymphs that girdle the plants with their feeding punctures. According to Bailey et al. (1970), *S. festinus* feeds mostly on the lower portion of the stems, but on soybean plants taller than 25.4 cm, the insect prefers to feed on leaf petioles.

Girdled plants are weakened and may break over and lodge during high wind or heavy rains. Plant lodging may cause a stand reduction which may be associated with yield loss. In South Carolina and Oklahoma (Anonymous, 1975), *S. festinus* has caused economic damage to soybeans. Tugwell and Miner (1967) in Arkansas found that the hoppers girdled up to 55.2% of the plants, but caused no yield loss.

In addition to plant girdling, *S. festinus* may also indirectly affect soybean plants by transmitting or predisposing the plants to a fungal disease. The wounds made by the hoppers through feeding punctures provide entry for *Sclerotium rolfsii* Saccardo, the causal agent of sclerotial blight (Herzog et al., 1975).

Lesser cornstalk borer. Several researchers including Luginbill and Ainslie (1917), King et al. (1961), Walton et al. (1964), Dupree (1965), and Leuck (1966) have made a complete study that included the biology and description of life stages of the lesser cornstalk borer.

The larvae of E. lignosellus feed on a variety of host plants, mostly grasses and legumes (Luginbill and Ainslie, 1917; Dempsey and Branthey, 1953; and Jordan, 1965). They damage soybeans by tunneling into young plants and girdling the stem of older ones. Small plants so injured wilt and usually die; damaged older plants may be broken off by high winds.

Isely and Miner (1944) reported that in northwestern Arkansas, lesser cornstalk borer infestations were so high that more than 50% of the stand was lost in the fall beans. In one field, 80% of the bean plants were killed 10 days after the plants emerged.

Genung and Green (1965) reported that E. lignosellus infestations on Florida soybeans were light and confined to young plants, but that all the plants attacked died. Severe infestations occur most frequently in sandy soils and are usually associated with late planting or drought stress (Leuck, 1966; Turnipseed, 1973).

Soybean looper. The soybean looper [Pseudoplusia includens (Walker)] females preferentially oviposit on

vegetables and legumes (Deitz et al., 1976). Mitchell (1967) studied the life cycle of P. includens on soybeans.

Hensley et al. (1964) and Canerday and Arant (1966) reported that soybeans, peanuts, and sweet potatoes were the most preferred hosts for P. includens. On soybeans the loopers may inflict severe foliage damage and occasionally they cause damage to pods in the Gulf states (Deitz et al., 1976).

Velvetbean caterpillar. Watson (1916), Douglas (1930, and Greene et al., (1973) are some of many researchers who studied the life history and described the stages as well as feeding and mating behavior of Anticarsia gemmatilis Hubner. The eggs are laid on all portions of the soybean plants (Strayer, 1973), and require three days to hatch in August and September, and at least seven days in November, in Florida (Watson, 1916).

Watson (1916) and Douglas (1930) reported that the velvetbean caterpillars were preyed upon and parasitized by many species of birds and insects, but that the fungus Nomurea rileyi (Farlow) was the most important natural enemy that regulates populations of this pest.

The nature of damage caused by A. gemmatilis immatures to soybeans has been described by Watson (1916), Douglas (1930) and Hinds and Osterberger (1931). The first three instars cause less damage as they only remove the lower epidermis and mesophyll of the leaves. The last three instars,

however, will consume the whole leaf leaving only the midrib and large veins. When the infestations are high, the larvae eat up all the leaves and attack the tender portions of the stems, buds and small bean pods.

The velvetbean caterpillar is the most important defoliator of soybeans in north and central Florida where populations reach the peaks in late July, mid-August and early September (Strayer, 1973). Outbreak infestations during pod set and pod fill usually cause severe yield losses.

Brown and southern green stink bugs. Woodside (1946), DeCoursey and Esselbough (1962), and Mitchell and Mau (1969) described the stages and studied the biology of the brown stink bug, *Euschistus servus* (Say), and the southern green stink bug, *Nezara viridula* (L.).

Adult *E. servus* are grayish-yellow and measure 12.0-15.0 mm long. The eggs measure 1.2-1.3 mm in height, and hatch after 3-14 days in laboratory conditions (Rolston and Kendrick, 1961). The *N. viridula* eggs hatched after an average of 5.2 days in the laboratory. Both species pass through five nymphal instars, and have at least two generations per year. Hill (1975) reported three generations of *N. viridula* during nine months in Egypt; there are probably three or more in Florida (Sailer, personal communication, 1980).

The nature of stink bug damage to soybeans has been studied by many workers (Miner, 1961 and 1966; Daugherty et al., 1964; and Turner, 1967). Damage is caused when

nymphs and adults insert their mouthparts through the pods and into the beans to feed on the developing seed. Such seeds tend to shrivel and pods may abort when young pods are injured. Along with histolytic substances injected into the beans to liquefy cell contents, the bugs inject a yeast-spot disease fungus, *Nematospora coryli* Peglion which further lowers the quality of the beans.

In Arkansas, Miner (1961) observed that damage by *N. viridula* lowered the oil content and slightly increased protein content of the seeds. Blickenstaff and Huggans (1962) reported a decrease in the yield of soybean seeds and an increase in the percentage of small seeds due to stink bug damage.

Corn Insects

Lesser cornstalk borer. Some information pertaining to *E. lignosellus* has already been mentioned in the section of soybean insects. The feeding behavior of this insect on corn is the same as when it feeds on soybeans or other host plants.

According to Luginbill and Ainslie (1917), the lesser cornstalk borer attacks corn plants at, or just below the ground level. The larvae bore or tunnel into the stem of seedling plants and feed on roots or above the soil surface. Young plants so injured die quickly. Some infested plants may survive, but become distorted, curled and one sided.

On older corn, the larvae girdle the stems, although they may also tunnel into the stems. Metcalf et al. (1962) reported that when corn under 45 or 50 cm is damaged it fails to produce ears or good stalks.

Fall armyworm. The fall armyworm, Spodoptera frugiperda (J. E. Smith), is an important agricultural pest; the larvae feed on, and cause yield losses to, a variety of field, forage and vegetable crops (Luginbill, 1928).

Luginbill (1928) reported a very detailed study that included the biology and description of life stages of this pest. On corn, female S. frugiperda deposit the egg masses on the underside of the leaves. Oviposition occurs at night, and the incubation period lasts from two to ten days. The larvae mature, on the average, 10.9 to 13.4 days after they hatch. Pupation takes place in the soil in loose cocoons; adult moths emerge after 7-37 days. In Florida, moths emerged from buried pupae after 14-35 days (Wood, 1977).

The larvae of S. frugiperda are almost omnivorous, but do show a marked preference for Gramineae (Luginbill, 1928). The first instars skeletonize the leaves and make holes while the fourth to sixth instars usually completely destroy small plants and strip larger ones.

Morrill and Green (1973) found that young larvae fed on the upper portions of corn plants whereas larger larvae

were found in whorls and furls. Fall armyworms also attack corn ears by burrowing into them either from the tip or from the side.

Corn earworm. The eggs of the corn earworm, *Heliothis zea* (Boddie), hatch from two to eight days after oviposition, and the larval period lasts 13-28 days (Phillips and Barber, 1931). Mature larvae leave the host plants and drop to the ground to pupate under the soil surface in pupal cells. Pupation takes about 14 days.

Corn earworm has been characterized as the "worst pest of corn" in the U. S. (Metcalf et al., 1962). In a five-year study in Florida, Janes (1973) found that *H. zea* was the most important insect pest on the ears of sweet corn.

Although corn earworms may seriously damage the foliage of early planted corn, they cause more severe damage when they feed on ears where they may destroy most of the kernels (Phillips and Barber, 1931). Phillips and Barber (1931) observed that the larvae will leave all other parts of corn plants to attack silks and ears when these plant parts appear.

In the U. S., up to 70-98% of the ears of field corn may be infested during outbreak infestations, and as much as 5 to 7% of the kernels of field corn and 10-15% of canning corn may be destroyed by the larvae (Metcalf et al., 1962).

Soil-Inhabiting Predators

Carabid Beetles

Several species of carabid beetles constitute a group of predators that play an important role in regulating pest populations in various agroecosystems. Members of the genera *Calosoma*, *Pasimachus*, *Progaleritina*, etc., have been reported as predators of arthropod pests, especially Lepidoptera larvae (Stone, 1941; Whitcomb and Bell, 1964; van den Bosch and Hagan, 1966; and Neal, 1974).

Calosoma sayi Dejean is one of the most commonly encountered carabid predators in Florida soybean fields. Watson (1916), Nickels (1926), Douglas (1930), and Hasse (1971) observed this carabid preying on larvae and pupae of *A. gemmatilis*. Price and Shepard (1978) observed a build-up of adult *C. sayi* as a response to outbreaks of noctuid larvae in soybean fields in South Carolina. They also found a significant correlation between weekly populations of noctuid larvae and numbers of *C. sayi* from mid-August to soybean defoliation.

In Florida, Neal (1974) observed *C. sayi* on soybean plants during daytime, but no predatory activity was observed. He reported that the carabid shows predatory activity only at night. Whitcomb and Bell (1964), however, mentioned that the predator fed on larvae of *Alabama argillacea* (Hubner) during daytime.

Neal (1974) recorded three species of *Pasimachus* in north Florida soybean fields. Only one species, *P. sublaevis* Beauvois, was common; the other two, *P. subsulcatus* Say and *P. strenuus* LeConte, were collected once and twice, respectively. Blatchley (1910) reported that *Pasimachus* spp. feed on a variety of larvae. In soybean fields Neal (1974) observed *P. sublaevis* preying upon various insects including larvae of *C. sayi*, velvetbean caterpillars, and crickets.

Three species of the genus *Harpalus* were collected in pitfall traps in Quincy, Florida (Neal, 1974). The *H. caliginosus* (Fabr.) was the least common, *H. gravis* LeConte was active from August to mid-September, and *H. pennsylvanicus* De Geer was active from mid-August to the middle of October. *Harpalus pennsylvanicus* was found feeding on larvae and pupae of *A. gemmatilis* and *Gryllus* spp. nymphs. Plant matter was also found in the gut content (Neal, 1974).

Progaleritina spp. are reported to feed only on arthropods; no plant material was found in their gut (Neal, 1974). Adults were observed feeding upon various noctuid larvae, Mexican bean beetle larvae, and cricket nymphs. *Progaleritina lecontei* Dejean is the most common of the three species (*P. janus*, *P. bicolor*) found in north and central Florida. Adults are active in soybean fields from mid-August through the middle of September (Neal, 1974).

Thiele (1977) made a detailed study of carabid beetles in relation to their habitats including the effects of cultural practices on carabid populations. Kabacic-Wasylik (1970, cited by Thiele, 1977) found that during rotation from one crop to another, the spectrum of dominance of carabids undergoes a corresponding shift.

The Striped Earwig

The striped earwig, *Labidura riparia* (Pallas), is an important soil-inhabiting predator and its biology and predatory behavior have been studied by several researchers (Schlinger et al., 1959; Afify and Farghaly, 1970; Caussanel, 1970, Tawfik et al., 1972; and Ammar and Farrag, 1974).

Adult *L. riparia* mate on the soil surface or in shallow tunnels, but the eggs are laid in deeper (average depth 5.8 cm) tunnels (Ammar and Farrag, 1974), which have no passage to the soil surface (Caussanel, 1970). The eggs hatch after an average of 9.9 days at 22-25° C. The females brood over the eggs, and bring food to newly hatched nymphs. The insect passes through six nymphal instars.

Tawfik et al. (1972) observed *L. riparia* climbing corn plants in search of prey. They also reported that this earwig fed on a variety of prey including such important pests as *Spodoptera littoralis* Boisd., *Pieris rapae* L., *Vanessa cardui* L., etc. A fifth- or sixth-instar nymph *L. riparia* may consume up to 4-7 young larvae or 2-4 large

larvae of S. littoralis per day. Dean and Schuster (1958) and Clements (1968) reported that the striped earwig preyed on armyworms, mites, scale insects, and aphids. In a laboratory study, Schlinger et al. (1959) found that L. riparia fed on various insects including Lepidoptera of all stages, elaterid larvae, aphids, and carabid larvae. Labidura riparia was also observed feeding on A. gemmatilis larvae, pupae and adults, L. riparia nymphs, small Calosoma larvae, Gryllus nymphs, wolf spiders, and adult Heliothis spp. (Neal, 1974).

Hassanein et al. (1968) and Afify and Farghaly (1970) compared the predatory effectiveness of L. riparia and that of Coccinella undecimpunctata Reiche on the cottonworm, Prodenia litura Fabr. and S. littoralis. They found that L. riparia was more efficient than Coccinella as an egg and larval predator.

Price and Shepard (1977) investigated the patterns of colonization of soybean fields as well as the response to insecticides by L. riparia. The authors observed lower numbers in newly established fields than in older ones. Soybeans treated with methyl-parathion and methomyl early in the season had higher earwig populations than untreated fields. Reduction in numbers of ants and other insects that prey on earwigs, after insecticidal applications, was believed to be the reason for these lower populations.

CHAPTER II

SOYBEAN CROP SYSTEMS

Materials and Methods

Cultural Practices

Rye stubble experiment. Experiments were conducted simultaneously on the Robinson farm located in Williston, Levy county, about 33 km west of Gainesville, and at the Green Acres, a University of Florida agronomy farm located in Alachua county. These two locations will be referred to as Williston and Green Acres.

In Williston the observations were made in a large block measuring 73.17 m x 85.37 m previously planted to rye which was used either as hay (stubble) or mulch. The block was divided into four 12.20 m x 73.17 m main plots separated from each other by a 12.20 m wide alley. Each main plot was further divided into six 12.20 m x 12.20 m small plots making a total of 24 small plots for the whole block. Six tillage treatments were arranged in a randomized complete block design with each treatment being replicated four times. The six treatments whose effects were tested on insect populations were:

1. no tillage into rye stubble: "Cobb" soybeans were seeded directly (without any previous soil preparation) into the stubble of "Wrens Abruzzi" rye.
2. no tillage plus in-row subsoil into rye stubble: This treatment was the same as the first one except for the additional subsoiling made in the rows during the planting operation.
3. no tillage into rye mulch;
4. no tillage plus in-row subsoil into rye mulch.
5. conventional tillage into rye stubble: The soil in the conventional tillage plots was prepared according to the normal tillage practice (moldboard plowing and disking) before soybeans were planted.
6. conventional tillage plus in-row subsoil into rye stubble.

"Cobb" soybeans were planted in all the plots on March 21, 1978, in 76.2 cm rows with a 2-row Brown-Harden Super-seeder® mounted on a 4600 Ford tractor. Seedling rate was about 112 kg/ha. The plots were fertilized with 672 kg/ha of 5-4.4-12.5 N-P-K applied at planting along with 0.42 kg a.i./ha of paraquat (see Appendix A for chemical names of all herbicides) plus Ortho X-77 (surfactant)at the label dose, 2.24 kg a.i./ha of alachlor and 0.28 kg a.i./ha

paraquat (with X-77) was made on April 10, 1978. No insecticide was used in this experiment.

Corn stubble experiment. A second crop of soybeans was grown at Williston from August to November, 1978. The plots were close to, and of the same size as, those in the first season and were previously planted to corn (following rye) without any soil preparation except in the conventional tillage plots. The same six tillage treatments as above were evaluated in corn residues. The agronomic practices were the same as in the first experiment except that the plots were sprayed with methomyl at the rate of 0.56 kg a.i./ha on September 27, 1978, for the control of the velevebean caterpillars.

Oat stubble experiment. The Green Acres experiment was conducted from June to the middle of October, 1978, in a block that was previously planted to "Florida 501" oats (*Avena sativa* L.). The following four tillage treatments were studied in this experiment:

1. no tillage into oat stubble
2. no tillage plus in-row subsoil into oat stubble
3. conventional tillage into oat stubble
4. conventional tillage plus in-row subsoil into oat stubble.

Conventional tillage plots were prepared on June 2, 1978, with a moldboard plow and were disked twice. The

same cultivar of soybeans was planted in all the plots on June 3, 1978. The entire field was fertilized with 448 kg/ha of 5-4.4-12.5 N-P-K applied at planting. Metribuzin (0.28 kg a.i./ha), linuron (1.12 kg a.i./ha), and paraquat (0.42 kg a.i./ha) were also applied during the planting operation for weed control. No-tillage plots were also treated (directed sprays) with paraquat (0.28 kg a.i./ha) plus X-77 (surfactant) on June 29 and July 19, 1978. Each tillage treatment was divided into two portions; one half of the plot was treated with carbofuran at the rate of 1.12 kg a.i./ha to control soil insects. The other half was untreated and was used as a control. When populations of velvetbean caterpillars and stink bugs became high, all the plots were sprayed with methomyl (0.56 kg a.i./ha) on August 17 and September 7, and with acephate (0.84 kg a.i./ha) on September 13, 1978.

This experiment was repeated on the same block in 1979. "Cobb" soybeans were planted on June 12, 1979, according to the same cultural procedure as in the 1978 season except that carbofuran (or any other insecticide) was not used at planting. The plots were sprayed with acephate on August 30, 1979, to control the velvetbean caterpillars and on October 5, for stink bug control.

Estimation of Tillage Effects on Insects

Soil arthropods. Damage caused by the lesser cornstalk borer was assessed by visual observations. Two different rows were randomly selected in each replication every week,

and all the plants in the row were carefully examined. Stunted, infested plants were pulled, counted and the number recorded. Infestation levels were calculated as the number of infested plants per row.

Populations of cutworms and soil-inhabiting predators (earwigs, spiders and carabid beetles) were monitored by means of pitfall traps. The traps consisted of cottage cheese cups about one-third filled with ethylene glycol that killed and preserved the catches. In order to prevent rains from filling the traps and to avoid disturbance of the traps by small animals, a piece of wood (20 cm x 20 cm x 0.5 cm) was positioned about 4 cm above each trap. One trap was placed in the middle of each replication and positioned within the row in order to prevent destruction by machines during farming operations. The traps were set in the plots from two days to two weeks after soybeans were planted. The insects were collected every week and brought into the laboratory where they were sorted by species and the numbers of each species recorded.

Above-ground insects. Soybean looper, velvetbean caterpillar and stink bug populations were estimated by the plant shaking method. In 1978 two sample sites were randomly selected in each replication, but only one site was used in the 1979 crop season. After selecting the site the shake cloth was unrolled on the ground between two plant rows, and the plants over the cloth were shaken vigorously enough

to dislodge the insects which then fell onto the cloth. The insects were counted and numbers recorded by species. The shake cloth method was also used in the 1978 experiments to estimate population levels of the three-cornered alfalfa hoppers. Because adult hoppers fly quickly when disturbed, this method was abandoned in 1979. The sweep net method, as described by Boyer (1967) (method 1) was used instead.

Stink bug damage to seeds was determined (at Green Acres only) at the end of the season when the beans were dry and ready to be harvested. Three soybean plants were randomly chosen in each replication while walking diagonally across the plot. A total of 12 plants were observed for each treatment. All the pods were collected from each plant and placed into a paper bag. The bags containing the pods were brought into the laboratory and the seeds were examined for stink bug damage. The total number of seeds as well as number with at least one feeding puncture were recorded. The number of small, wrinkled seeds was also recorded. The number of plants selected per replication was increased to five in the 1979 experiment. This increase resulted in 20 plants observed per treatment.

All the data were transformed (log. transformation for numbers and arcsin transformation for percentages) before they were submitted to the statistical analysis.

An effort was made to relate fluctuations of pest and predator populations to the phenology of the plants.

Developmental stages of the soybeans were recorded weekly according to the method described by Fehr and Caviness (1977).

Results and Discussion

Soil-Pest Insects

Lesser cornstalk borer infestations were not assessed in the rye stubble experiment at Williston. Table 1 contains the results obtained from the corn stubble experiment. Although the weekly average number of infested plants per row was 2.04 in the conventional tillage and 1.92 in the no-tillage treatment, the analysis of variance was not significant. The results also indicated that in-row subsoiling did not affect E. lignosellus infestations, and that corn stubble was not statistically different from corn mulch with respect to lesser cornstalk borer infestations.

In 1978 some plants were killed by paraquat in the no-tillage plots at Green Acres (oat stubble experiment); this made observations difficult. Lesser cornstalk borer damage was, therefore, estimated only in the 1979 season. The results from the 1979 oat stubble experiment are shown in Table 2. Damage levels were significantly (P=0.01) higher in the no-tillage soybeans than in the conventional tillage soybeans. The weekly average number of damaged plants per

row was 4.29 and 1.42, respectively for the no tillage and conventional tillage. In-row subsoil had a significant impact on the borer infestations. The average number of infested plants was significantly lower in the no tillage plus subsoil than in the no tillage without subsoil. Infestations were also lower in the conventional tillage with subsoil than in the conventional tillage without subsoil (Table 2).

Damage to soybean seedlings was very low during the two seasons at both Williston and Green Acres. The method used here to determine borer infestations, although commonly used, certainly underestimated infestation levels because only wilted and dead plants were detected and counted. Older seedlings do not wilt when infested. Collecting randomly a certain number of plants, wilted or not, throughout the field and examining roots and lower portions of the stems for borer infestation might have resulted in a better estimation of the damage.

In one experiment, the results showed that no-tillage systems were not conducive to the buildup of lesser cornstalk borer infestations as compared to the conventional tillage. Results from another experiment, however, showed that E. lignosellus can be a more serious threat to no-till soybeans than to the conventionally tilled soybeans. The lesser cornstalk borers may remain in weeds or crop debris from which they migrate to attack crop seedlings (All and Gallaher, 1977). Crop residues and the lack of soil disturbance in

no-tillage systems would seem to explain why infestations were higher than those observed in the conventional tillage at Green Acres. However, crop debris left on the ground have been reported to reduce E. lignosellus infestations in no-tillage corn (All et al., 1979).

Above-Ground Pest Insects

Three-cornered alfalfa hopper. Hopper populations were monitored during 1978 and 1979 only at Green Acres. The plant shaking method was used in 1978, but was abandoned in 1979. The number of Spissistilus festinus (Say) collected was very low and most were nymphs thus confirming Boyer's (1967) earlier conclusion regarding inadequacy of the method. Therefore, during the 1979 season the sweep net was used, and numbers of S. festinus collected were relatively high. The average numbers of hoppers recorded from each tillage system are shown in Table 3 for both the 1978 and 1979 crop seasons.

The data indicated the hopper populations were statistically the same in all tillage treatments in 1978. Although the average number of hoppers was about three times higher in the no-tillage soybeans than in the conventional tillage plots in 1979, analysis of the data did not show any significant differences between treatment means. Spissistilus festinus did not manifest any preference for no-tillage soybeans as compared to the conventional tillage.

Soybean looper. Early-planted (April-July, 1978) soybeans in the Williston rye stubble experiment were not infested by the soybean looper, P. includens, and only trace numbers of loopers were recorded in the corn stalk experiment (late planted, August) at Williston. Numbers of loopers recorded in both 1978 and 1979 seasons at Green Acres are shown in Table 4. Looper populations were relatively low during the two seasons, but were higher in 1978 than in 1979. An average of 1.04 and 1.34 loopers per shake was recorded respectively from the no tillage and conventional tillage in 1978. In 1979, only 0.67 and 0.33 loopers per shake were collected from both treatments, respectively.

Such low looper populations were not believed to have caused significant damage to soybeans. No significant differences were detected between treatments for P. includens populations estimated by the plant shaking method. The no-tillage farming did not effect oviposition by Pseudoplusia moths (which may be attracted by plant residues) or the development of the larvae.

Southern green stink bug. The southern green stink bug, Nezara virdula (L.), was the most abundant of all species of stink bugs observed during the two years. The brown stink bug, Euschistus servus (Say), was the next abundant, but in trace numbers. Average numbers of N. viridula collected by the plant shaking method from Williston and Green Acres soybeans are shown in Tables 5, 6, and 7.

Results obtained from the first season at Williston (rye stubble experiment) showed that populations of the southern green stink bug were significantly (P=0.05) lower in the conventional tillage treatment than in any of the no-tillage treatments (Table 5). An average of 1.32 stink bugs per shake was collected weekly from the no-tillage soybeans, but only 0.96 stink bugs were collected from the conventional tillage. No significant differences were found between the two no-tillage treatments or between the conventional tillage and the conventional tillage plus in-row subsoil. Stink bug populations were very low in the corn stubble experiment at Williston.

Although N. viridula average population levels in the 1978 Green Acres experiment were 3.28 stink bugs per shake in the no tillage into oat stubble and 2.61 stink bugs per shake in the two conventional tillage treatments, analysis of variance was not significant (Table 6). In the 1979 experiment, population levels were generally high, but analysis of the data failed to show any significant differences among treatment means (Table 7). The weekly average for adult population was 4.94 and 4.88 stink bugs per shake, respectively, in conventional tillage and no-tillage soybeans. Stink bug damage to seed was assessed at the harvest time during the two years, and the results obtained are in Tables 8 and 9. In 1978, damage appeared to be lower in the no tillage with in-row subsoil than in all other treatments, but analysis

of data did not detect any significant differences among treatments. Analysis of data also revealed no significant differences between treatments in number of seed damaged. Although the percent of small, wrinkled and fungus-infected seeds was 38.92 in the no tillage into oat stubble and 19.28 in the conventional tillage, analysis of variance of the data was not significant (Table 9).

In 1978, stink bug populations at Green Acres reached the economic threshold recommended for Florida soybeans (Strayer and Greene, 1974). Peak levels (2.4 adults per shake average of all the treatments) occurred during the week of September 21 when soybeans were in R5-R6 stages (beginning and full seed stages; Fehr and Caviness, 1977). This peak followed three applications of methomyl, the last two being made on September 7 and 13, 1978. Methomyl did not apparently affect stink bug populations. In 1979, adult population was about four times higher than the recommended economic threshold.

Except the Williston first experiment in which populations of the southern green stink bug were significantly lower in the conventional tillage than in no-tillage treatments, the tillage systems studied in all other experiments did not show any significant effect on either stink bug populations or stink bug damage to soybeans. No-tillage systems in these experiments apparently did not provide a more favorable environment than that found in the conventional

tillage, in order to attract and harbor higher populations than those that would colonize conventionally tilled soybeans. Stink bugs are known to fly across the field from the area of the initial infestations in search of pods (Miner, 1966). Such movements are likely to reduce any effect that the no-tillage systems may have. On the basis of the data presented in Tables 5-9, it is believed that, when wild hosts are effectively eliminated from the no-tillage systems through good weed control, stink bug infestations are not likely to be more serious in these systems than in the conventionally tilled fields.

Velvetbean caterpillar. The early-planted (April-July, 1978) soybeans in the first Williston experiment (rye stubble) were not infested by velvetbean caterpillars. In the second season experiment, however, populations of A. gemmatilis reached such high levels that an application of methomyl was made on September 27. A weekly average of up to three large (over 2.5 cm) larvae per shake was recorded. Average numbers of caterpillars collected by the shake cloth method are contained in Table 10. The analysis of the data showed that no-tillage systems did not significantly affect population levels of either the small (up to 2.5 cm) or large larvae as compared to the conventional tillage.

Figures 1-3 show the weekly trend of small, large and total populations of the velvetbean caterpillars. Although

analysis of the data did not detect any significant differences between treatments, the figures show that before the plots were sprayed with methomyl, populations of small larvae were highest in the conventional tillage whereas populations of large larvae were highest in the no-tillage into corn mulch. After application of methomyl, populations of both age groups were highest in the no-tillage into corn stubble.

Data obtained from the Green Acres 1978 experiment also failed to show any significant effect of no-tillage treatment on velvetbean caterpillar populations as compared to the conventional tillage (Table 11, Figures 4, 5, and 6). After the second application of methomyl (September 7), all the larvae collected were very small (up to 1 cm) (Figures 4, 5 and 6). Soybeans were in the R5-R6 stage and these small larvae could not cause any significant damage to the soybeans.

In 1979 at Green Acres velvetbean caterpillars were classified into small (up to 1.5 cm), medium (1.6-2.5 cm), and large (over 2.5 cm) larvae. The average numbers of larvae per shake for each age group are shown in Table 12, and the weekly population trend is illustrated by Figures 7, 8 and 9. Populations of small larvae were significantly (P=0.05) lower in no-tillage into oat stubble than in the conventional tillage treatments or in no-tillage plus in-row subsoil. Figure 7 shows that throughout the cropping season,

populations of small larvae were consistently lower in the no-tillage than in the conventional tillage except for the weeks of August 23 and September 13. No-tillage treatments did not significantly affect medium and large larval populations (Table 12 and Figure 8).

The exact reason for fewer small larvae observed in the no tillage than in the conventional tillage is not known. This might have been an indication that A. gemmatilis moths preferred to oviposit in the conventional tillage soybeans which were cleaner than the no-tillage soybeans with some weeds and crop resideus. Sloderbeck and Edwards (1979) found that adults and larvae of the Mexican bean beetle preferred tilled to nontilled soybeans. The authors believed that this might have been due to "a preference of adult beetles for the tilled soybeans" which were almost free of weeds and residues.

Soil-Inhabiting Predators

Ground spiders. Populations of ground spiders were monitored at Green Acres along with those of soil insects. Since no attempt was made to identify the different species of spiders collected in pitfall traps, all the species will be collectively referred to as ground spiders.

In 1978 spider populations were statistically identical in conventional tillage and no-tillage plots. The weekly average numbers were 1.0 and 1.7 spiders per trap, respectively,

in the no tillage and conventional tillage. In-row subsoil did not significatnly affect spider populations either in conventional tillage treatments or in no-tillage plots.

Spider populations reached the peak about four weeks before the peaks of pest populations. During the week of peak populations the average number for the entire field (all treatments combined) was 3.91 spiders per trap. Ground spiders were in low numbers (field average, 0.41) when most pest species increased in number.

In 1979 spider populations were high and peaked during the second week of the sampling period, i.e. before most pest species appeared. The analysis of data revealed no significant differences between treatments. The weekly average numbers were 3.78 and 2.40 spiders per trap in conventional tillage and no-tillage soybeans, respectively.

A reduction in number of spiders in a crop system may result in increased pest populations in that system since spiders constitute an important part of the predator complex in crop systems (Whitcomb and Bell, 1964). The activity of spiders, as indicated by the results, was not affected by the tillage systems investigated in this study.

Striped earwig. Average numbers of the striped earwig, Labidura riparia, observed at Williston from April to July 1978 are in Table 13. Both nymphal and adult populations were significantly (P=0.05) lower in the conventional tillage

plus in-row subsoil than in any of the no-tillage treatments. The conventional tillage plus in-row subsoil also harbored significantly more earwigs than the conventional tillage without subsoil. Adult populations were significantly higher in no tillage into rye stubble and no tillage into rye mulch than in the conventional tillage (Table 13). No till into rye stubble did not significantly differ from no till into rye mulch.

Figures 10, 11 and 12 show the weekly trend of nymphal, adult and total populations of Labidura respectively in no tillage into rye stubble, no tillage into rye mulch and conventional tillage treatments. Earwig populations remained higher in the no tillage into rye mulch than in any of the other two treatments during the first half of the sampling period.

Earwig populations were very high in the second season at Williston. An average of up to 245.77 nymphs and adults per trap were collected from one treatment (Table 14). Although populations appeared to be highest in the no till plus in-row subsoil into corn mulch, analysis of the data did not detect any significant differences between treatment means. This was also shown by Figures 13, 14, and 15 which illustrate weekly foraging activity of the earwigs in the conventional till, no till into rye-corn stubble and no till into rye-corn mulch.

The average numbers of Labidura collected in pitfall traps at Green Acres in 1978 are in Table 15. Except for the conventional tillage plus in-row subsoil, nymphal populations in all other treatments appeared to be higher in the carbofuran-treated portion than in the untreated other half of the plots. The differences among treatment means, however, were not significant for either nymphs or adults. Price and Shepard (1977) also found that soybeans treated with insecticides harbored more earwigs than untreated ones. When the untreated no tillage was compared to the untreated conventional tillage for adult populations, it was found that the conventional tillage harbored significantly more adult Labidura than did the no tillage (Table 15). The weekly activity of the earwigs in no tillage and conventional tillage is shown in Figures 16, 17, and 18.

Table 16 contains average numbers of nymphs and adult Labidura collected at Green Acres in 1979. Nymphal and adult populations appeared to be higher in the conventional tillage than in the no tillage, but the analysis of the data failed to show any significant differences among treatments.

Colonization patterns of no-tillage soybeans by L. riparia did not differ from those of the conventionally tilled soybeans, and were similar to those reported by Price and Shepard (1977) for conventional tillage soybeans. Young, newly established no-tillage and conventional till

soybeans had very low earwig populations. In the first-season experiment in Williston the earwig populations reached peak at the end of the sampling season. In the second experiment, however, populations peaked at the beginning of the season (Figure 15), when soybeans were in the V4-V5 stages. At Green Acres in 1979 populations remained relatively high in the conventional tillage at the end of the sampling period, but were very low in the no tillage. The average nymphal population was almost zero in the no tillage at the end of the season (Figures 19, 20, and 21).

The results indicated that no-tillage farming did not generally affect populations of *L. riparia*. This earwig was active and in large numbers throughout the second half of the crop season, when pest species appeared or were in large numbers. *Labidura* did not apparently have any significant impact on pest populations; no noticeable reduction of pest populations was observed in spite of large *Labidura* populations. This of course does not rule out the possibility that the pest populations would have been higher in the absence of *L. riparia*. In confinement this earwig killed many more *Anticarsia* larvae than it consumed (see Appendix B).

Carabid beetles. Fifty carabid beetles belonging to eight different species were collected in pitfall traps from April to

July, 1978, in rye stubble at Williston. The different species recorded are in Table 17. Colliuris pennsylvanica (L.) was the most abundant carabid species, representing 34% of all the species collected. Harpalus caliginosus Fab. was the next species with 18%. Anisodactylus merula Germar and Pasimachus sublaevis Beauv. each comprised 16% of the total population.

With respect to tillage systems, the results indicated that carabids were more active in no-tillage plots than in conventional tillage plots. No carabid beetles were collected from the conventional tillage during the entire sampling period (Table 17). The conventional till plus in-row subsoil, like no till plus in-row subsoil and no tillage into rye mulch, harbored 16% of the beetles each. The majority of carabids were collected from no till into rye stubble (30%) and no tillage plus in-row subsoil into rye mulch (22%).

The total number of carabid beetles collected from no-till and conventional till soybeans increased to 112 in the corn stubble experiment at Williston. Table 18 shows the different species and numbers of beetles recorded. The highest population (25.89%) of carabids was recorded from the no till plus in-row subsoil into corn stubble. No tillage into corn stubble harbored 18.75% of the carabids collected, and the conventional till contained the lowest (12.50%) population of carabid beetles. Over 43% of the

carabid beetles collected were P. sublaevis. Anisodactylus merula was the next abundant (11.61%) species collected.

Populations of carabid beetles were relatively high at Green Acres in the 1978 oat stubble experiment where a total of 320 carabids were collected (Table 19). Harpalus pennsylvanicus De Geer, A. merula and Calosoma sayi Dejean were the most abundant species counting for 45.31, 37.19, and 14.38% of the total, respectively. The no till into oat stubble had the highest (46.86%) carabid population, and the conventional tillage had the lowest with 14.69%. In 1979, the numbers were low at Green Acres; 81 individuals only were collected, with 34.57% from the no-tillage soybeans and 20.98% from the conventionally tilled plots. Harpalus pennsylvanicus and C. sayi were the most prevalent species representing 39.51 and 23.46%, respectively. The species and numbers of carabid beetles collected at Green Acres in 1979 are shown in Table 20.

Data collected over two years showed that no-tillage systems significantly increased the activity of carabid beetles. However, catches of most species were so erratic and their numbers so low that it is not believed that carabid beetles played any important role in regulating pest populations.

Table 1. Infestations of the lesser cornstalk borer, Elasmopalpus lignosellus (Zeller), in no-tillage and conventional tillage "Cobb" soybeans at Williston, Levy Co., Fla., 1978. Numbers are totals and averages of two rows per replication for three weeks.

	Infested plants	
Treatment*	Total Number	Average/row**
No tillage into corn stubble (in rye residue)	46	1.92
No till plus in-row subsoil into corn stubble (in rye residue)	32	1.33
No tillage into corn mulch (in rye residue)	46	1.92
No tillage plus subsoil into corn mulch (in rye residue)	41	1.71
Conventional tillage (into corn stubble)	49	2.04
Conventional tillage plus in-row subsoil	51	2.13

*In no-till plots corn was seeded into rye stubble (hay) or mulch and soybeans into corn stubble or mulch (following corn).

**In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 2. Lesser cornstalk borer infestations in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1979. Estimations are based on two different rows observed weekly (for three weeks) in each replication (four reps/treat.).

Treatment	Infested plants	
	Total Number	Average/row*
No tillage into oat stubble	103	4.29a
No tillage plus in-row subsoil into oat stubble	46	1.92b
Conventional tillage into oat stubble	34	1.42b
Conventional tillage plus in-row subsoil into oat stubble	20	0.83c

*Values not followed by the same letter are significantly different at the 0.05 level by Duncan's new multiple range test.

Table 3. Average number of the three-cornered alfalfa hopper, *Spissistilus festinus* (Say), collected by the plant shaking method (1978) and sweep net (1979) from conventional tillage and no-tillage soybeans at Green Acres, Alachua Co., Fla. Numbers are averages of eight weeks with eight shakes per treatment and three weeks with eight sweeps per treatment.

Treatment	No. hoppers collected* Avg./shake	Avg./sweep
No tillage into oat stubble	0.55	3.38
No tillage plus in-row subsoil into oat stubble	0.36	2.17
Conventional tillage	0.42	1.58
Conventional tillage plus in-row subsoil	0.42	1.83

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 4. Soybean looper populations in no-tillage and conventional tillage "Cobb" soybeans estimated by the shake cloth method at Green Acres, Alachua Co., Fla., 1978 and 1979. Numbers are totals and averages of eight (for 1978) and four (for 1979) weekly shakes (sites) per treatment for 12 (1978) and six (1979) weeks.

Treatment	Looper Population Total Number		Average/shake*	
	1978	1979	1978	1979
No tillage into oat stubble	100	16	1.04	0.67
No tillage plus in-row subsoil into oat stubble	137	5	1.43	0.21
Conventional tillage into oat stubble	129	8	1.34	0.33
Conventional tillage plus in-row subsoil into oat stubble	105	9	1.09	0.38

*No statistical analysis was done on the data the means being about equal.

Table 5. Effect of tillage on southern green stink bug populations estimated by the shake cloth method in "Cobb" soybeans at Williston, Levy Co., Fla., 1978. Numbers represent totals and averages of eight weekly shakes per treatment for seven weeks.

Treatment	Stink bug Population	
	Total Number	Average/shake*
No tillage into rye stubble	74	1.32ab
No tillage plus in-row subsoil into rye stubble	86	1.54b
No tillage into rye mulch	97	1.73b
No tillage plus in-row subsoil into rye mulch	106	1.89b
Conventional tillage into rye stubble	54	0.96a
Conventional tillage plus in-row subsoil into rye stubble	61	1.09ab

*Values followed by the same letter are not significantly different at 0.05 level by Duncan's new multiple range test.

Table 6. Number of *Nezara viridula* (Linn.) collected by the shake cloth method in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua, Co., Fla., 1978. The numbers represent totals and averages of eight weekly shakes per treatment for nine weeks. The plots (all) were treated with methomyl (once) and acephate (once) for insect control.

Treatment	Average/shake*		
	Nymph	Adult	Nymph + Adult
No tillage into oat stubble	1.19	2.08	3.28
No tillage plus in-row subsoil into oat stubble	0.56	1.58	2.14
Conventional tillage into oat stubble	0.83	1.78	2.61
Conventional tillage plus in-row subsoil into oat stubble	0.47	2.14	2.61

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 7. Number of *Nezara viridula* (Linn.) collected by the plant shaking method in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1979. Numbers are averages of four weekly shakes per treatment for four weeks. The plots were sprayed twice with acephate for insect control.

Treatment	Average/shake*			
	Nymph 1-3**	Nymph 4-5	Adult	N 4-5 + Adults
No tillage into oat stubble	2.94	1.69	4.88	6.56
No tillage plus in-row subsoil into oat stubble	1.38	1.19	4.69	5.88
Conventional tillage into oat stubble	1.06	1.50	4.94	6.44
Conventional tillage plus in-row subsoil into oat stubble	2.25	1.63	3.94	5.56

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

**1-5, first to fifth instars.

Table 8. Stink bug damage to seeds in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1978.

Treatment	Number of Seeds		
	Total Examined	Damaged	% Damaged*
No tillage into oat stubble	784	59	7.52
No tillage plus in-row subsoil into oat stubble	673	26	3.86
Conventional tillage	629	53	8.43
Conventional tillage plus in-row subsoil	532	40	7.52

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 9. Damage to seeds by the stink bug complex in no-till and conventional till "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1979. Numbers are averages of 20 plants per treatment.

Treatment	%*	
	Damage**	Small Seeds
No tillage into oat stubble	16.34	38.92
No-till plus in-row subsoil into oat stubble	14.25	28.87
Conventional till into oat stubble	15.02	19.28
Conventional till plus in-row subsoil into oat stubble	17.00	20.69

*In the analysis of the variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

**Damage: seeds with at least one feeding puncture. Small seeds: small, wrinkled and fungus infected seeds.

Table 10. Effect of tillage practice on populations of the velvetbean caterpillars, *Anticarsia gemmatilis* Hubner, estimated by the plant shaking method in "Cobb" soybeans at Williston, Levy Co., Fla., April - July, 1978. Numbers are averages of four weekly shakes per treatment for six weeks. Plots were treated with methomyl (0.56 kg a.i./ha) on September 27 for the control of velvetbean caterpillars.

Treatment	Average Number Larvae/shake*		
	Small	Large	Small + Large
No tillage into corn stubble	7.46	2.54	10.00
No tillage plus in-row subsoil into corn stubble	9.58	3.50	13.08
No tillage into corn mulch	6.92	3.21	10.13
No tillage plus in-row subsoil into corn mulch	7.54	2.71	10.25
Conventional tillage into corn stubble	8.33	2.46	10.79
Conventional tillage plus in-row subsoil into corn stubble	7.50	2.79	10.29

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 11. Effect of tillage practice on population levels of the velvetbean caterpillar, *Anticarsia gemmatilis* Hubner, monitored by the plant shaking method in "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1978. Numbers are averages of eight weekly shakes per treatment for eleven weeks for small larvae and eight weeks for large larvae. The plots were treated with methomyl and acephate (once each) for insect control.

Treatment	Average Number Larvae/shake*		
	Small	Large	Small + Large
No tillage into oat stubble	7.91	2.95	10.16
No tillage plus in-row subsoil into oat stubble	8.39	2.17	10.56
Conventional tillage into oat stubble	8.64	1.78	10.42
Conventional tillage plus in-row subsoil into oat stubble	8.50	3.45	11.95

*In the analysis of variance no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 12. Populations of the velvetbean caterpillar, *Anticarsia gemmatilis*, estimated by the plant shaking method in no-tillage and conventional tillage "Cobb" soybeans. at Green Acres, Alachua Co., Fla., 1979. Numbers represent four weekly shakes per treatment for ten weeks. Soybeans were treated twice with acephate for insect control.

Treatment	Average Number Larvae/shake*			
	Small	Medium	Large	Total
No tillage into oat stubble	11.43a	1.93c	1.78d	15.14e
No tillage plus in-row subsoil into oat stubble	16.13b	2.85c	2.15d	21.13f
Conventional tillage into oat stubble	17.15b	2.68c	1.10d	20.93f
Conventional tillage plus in-row subsoil into oat stubble	16.38b	2.90c	1.65d	20.93f

*Values in each column followed by the same letter are not significantly different at the 0.05 level by Duncan's new multiple range test.

Table 13. Activity of the striped earwig *Labidura riparia* (Pallas), in no-tillage and conventional tillage "Cobb" soybeans estimated by pitfall traps at Williston, Levy Co., Fla., 1978. Four traps were used for each treatment for 11 weeks.

Treatment	Earwig population		
	Average/trap*		
	Nymphs	Adults	Nymphs + Adults
No tillage into rye stubble	31.14ac	30.91c	62.05ac
No tillage plus in-row subsoil into rye stubble	31.64c	27.18a	58.82ad
No tillage into rye mulch	31.61c	30.25c	61.86c
No tillage plus in-row subsoil into rye mulch	31.27ac	26.91a	58.18d
Conventional tillage into rye stubble	30.34a	26.27a	56.61a
Conventional tillage plus in-row subsoil into rye stubble	22.59b	12.18b	34.77b

*Values followed by the same letter in each column are not significantly different at the 0.05 level by Duncan's new multiple range test.

Table 14. Activity of the striped earwig, *Labidura riparia*, in no-tillage and conventional tillage late-planted "Cobb" soybeans estimated by pitfall traps at the Robinson farm, Williston, Levy Co., Fla., 1978. Numbers are averages of three traps per treatment for ten weeks. Plots were treated once with methomyl for the control of velvetbean caterpillars.

Treatment	Average/trap*		
	Nymphs	Adults	Nymphs + Adults
No tillage into corn stubble	122.03	107.60	229.63
No tillage plus in-row subsoil into corn stubble	117.57	105.87	223.43
No tillage into corn mulch	125.03	101.50	226.53
No tillage plus in-row subsoil into corn mulch	136.40	109.37	245.77
Conventional tillage into corn stubble	118.20	111.13	234.13
Conventional tillage plus in-row subsoil into corn stubble			

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 15. Activity of the striped earwig, Labidura riparia, in no-tillage and conventional tillage "Cobb" soybeans estimated by pitfall traps at Green Acres, Alachua Co., Fla., 1978. Numbers are averages of 14 weeks with four traps per treatment. Half of each plot was treated with carbofuran (F) at planting, the other half was untreated (C).

Treatment		Average Number/trap*		
		Nymph	Adult	Nymph + Adult
No tillage into oat stubble	C	38.64	22.09cd	60.73cd
	F	42.88	24.48bc	67.36bc
No tillage plus in-row subsoil into oat stubble	C	35.57	19.16d	54.73d
	F	43.13	20.38d	63.50cd
Conventional tillage into oat stubble	C	44.39	35.57a	79.96ab
	F	52.68	34.00ab	86.68ab
Conventional tillage plus in-row subsoil	C	51.84	37.48ab	89.32ab
	F	49.50	33.13a	82.63a

*Analysis of variance not significant for nymphs. Values followed by the same letter in each column are not significantly different at the 0.05 level by Duncan's new multiple range test.

Table 16. Number of striped earwig, _Labidura riparia_, collected in pitfall traps in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1979. Numbers are averages of 15 weeks and four traps per treatment. All the plots were treated twice with acephate for insect control.

Treatment	Average/trap*		
	Nymphs	Adults	Nymphs + Adults
No tillage into oat stubble	26.95	21.13	48.08
No tillage plus in-row subsoil into oat stubble	41.30	24.42	65.72
Conventional tillage into oat stubble	43.55	36.12	79.67
Conventional tillage plus in-row subsoil into oat stubble	34.20	41.63	75.83

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 17. Species and numbers of carabid beetles collected in pitfall traps from no-tillage and conventional tillage soybeans at Williston, Levy Co., Fla., April - July, 1978. Totals of four traps per treatment for 12 weeks.

Species	Treatment*					
	CRS	CRS+s	NRS	NRS+s	NRM	NRM+s
Anisodactylus merula Germar	0	1	4	0	3	0
Calosoma sayi Dejean	0	0	1	0	0	0
Chlaenius laticollis Say	0	0	1	1	0	1
Colliuris pennsylvanica (L.)	0	2	4	5	1	5
Harpalus caliginosus Fab.	0	4	2	1	0	2
H. pennsylvanicus DeGeer	0	0	1	0	1	0
Pasimachus sublaevis Beauv.	0	0	1	1	3	3
Scarites subterraneus (Fab.)	0	1	1	0	0	0

*CRS-conventional tillage into rye stubble
CRS+s-conventional tillage plus in-row subsoil into rye stubble
NRS-no tillage into rye stubble
NRS+s-no tillage plus in-row subsoil into rye stubble
NRM-no tillage into rye mulch
NRM+s-no tillage plus in-row subsoil into rye mulch

Table 18. Species and numbers of carabid beetles collected in pitfall traps from no-tillage and conventional tillage soybeans at Williston, Levy Co., Fla., September - November, 1978. Numbers are totals of three traps per treatment for 10 weeks.

Species	Treatment*					
	CCS	CCS+s	NCS	NCS+s	NCM	NCM+s
Anisodactylus merula Germar	4	2	4	1	1	1
Calosoma sayi Dejean	0	0	1	1	2	5
Chlaenius tomentosus Say	0	0	0	0	1	1
Colliuris pennsylvanica (L.)	0	0	1	0	0	0
Galerita lecontei Dejean	0	0	0	2	0	0
Harpalus caliginosus Fab.	1	2	0	1	1	2
H. pennsylvanicus DeGeer	1	1	3	1	1	1
Pasimachus subsulcatus Say	1	1	1	2	2	0
P. sublaevis Beauv.	7	5	8	8	5	16
Solenophorus sp.	0	4	2	2	2	0
Scarites subterraneus (Fab.)	0	0	1	0	0	3

* CCS-conventional tillage into corn stubble
CCS+s-conventional tillage plus in-row subsoil into corn stubble
NCS-no tillage into corn stubble
NCS+s-no tillage plus in-row subsoil into corn stubble
NCM-no tillage into corn mulch
NCM+s-no tillage plus in-row subsoil into corn mulch

Table 19. Species and numbers of carabid beetles collected in pitfall traps from no-tillage and conventional tillage soybeans at Green Acres, Alachua Co., Fla., June - September, 1978. Totals of four traps per treatment for 14 weeks.

Species	Treatment*			
	CT	CT+s	NOS	NOS+s
Anisodactylus merula Germar	8	8	80	23
Calosoma sayi Dejean	18	14	6	8
Colliuris pennsylvanica (L.)	2	1	1	1
Galerita janus Fab.	0	0	0	1
Harpalus caliginosus Fab.	0	0	1	0
H. pennsylvanicus DeGeer	19	39	60	27
Pasimachus subsulcatus Say	0	0	2	0
Scarites subterraneus (Fab.)	0	0	0	1

*CT-conventional tillage
CT+s-conventional tillage plus in-row subsoil
NOS-no tillage into oat stubble
NOS+s-no tillage plus in-row subsoil into oat stubble

Table 20. Species and numbers of carabid beetles collected in pitfall traps from no-tillage and conventional tillage soybeans at Green Acres, Alachua Co., Fla., June - September, 1979. Totals of four traps per treatment for 15 weeks.

Species	Treatment*			
	CT	CT+s	NOS	NOS+s
Anisodactylus merula Germar	2	5	4	4
Calosoma sayi Dejean	3	2	8	6
C. scrutator (Fab.)	1	0	0	0
Chlaenius tomentosus Say	2	1	0	0
Colliuris pennsylvanica (L.)	1	0	0	0
Galerita lecontei Dejean	2	0	1	5
Harpalus caliginosus Fab.	0	0	0	1
H. pennsylvanicus DeGeer	5	5	15	7
Scarites subterraneus (Fab.)	1	0	0	0

*CT-conventional tillage
CT+s-conventional tillage plus in-row subsoil
NOS-no tillage into oat stubble
NOS+s-no tillage plus in-row subsoil into oat stubble

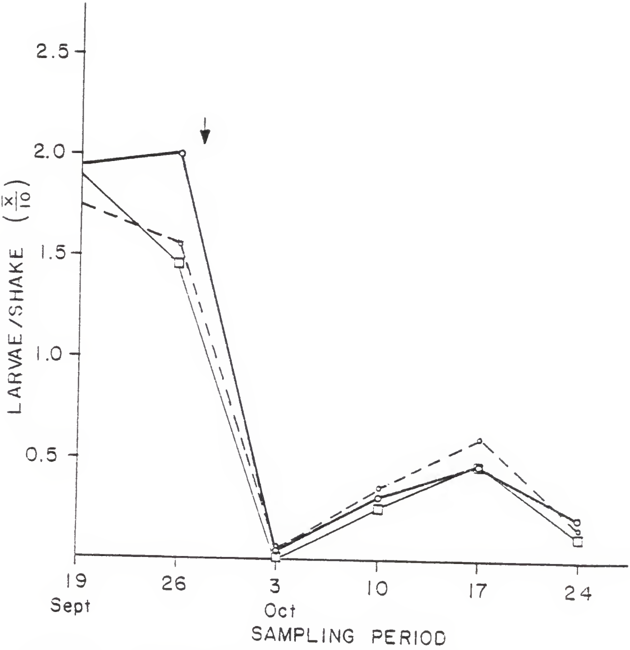


Figure 1. Average numbers of small (up to 2.5 cm) velvetbean caterpillars, Anticarsia gemmatilis, collected by the plant shaking method from no-tillage and conventional tillage "Cobb" soybeans at Williston, Levy Co., Fla., 1978. Averages of eight shakes per treatment.

——: conventional tillage
----: no tillage into corn stubble
—□—: no tillage into corn mulch
Arrow indicates insecticidal treatment

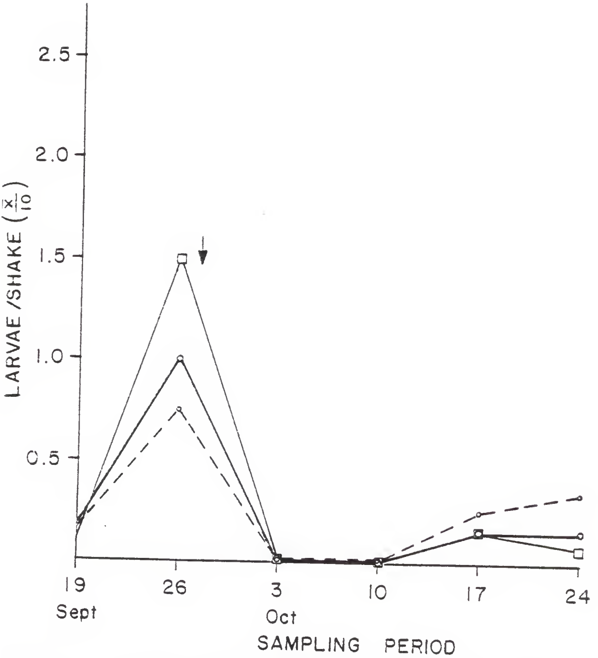


Figure 2. Average numbers of large (over 2.5 cm) velvetbean caterpillars, Anticarsia gemmatilis, collected by the plant shaking method from no-tillage and conventional tillage "Cobb" soybeans at Williston, Levy Co., Fla., 1978. Averages of eight shakes per treatment.

——: conventional tillage
----: no tillage into corn stubble
—□—: no tillage into corn mulch
Arrow indicates insecticidal treatment

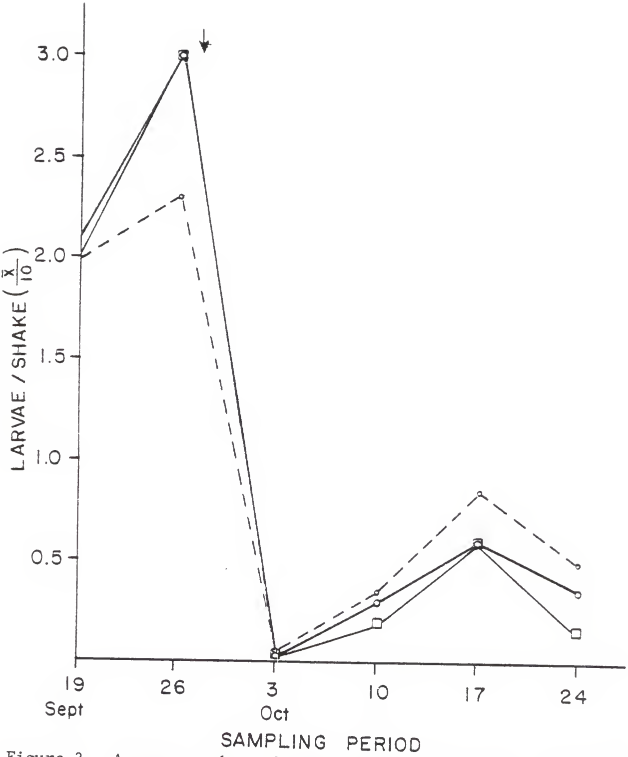


Figure 3. Average number of velvetbean caterpillars, Anticarsia gemmatilis, collected by the plant shaking method from no-tillage and conventional tillage "Cobb" soybeans at Williston, Levy Co., Fla., 1978. Averages of eight shakes per treatment.

——: conventional tillage
----: no tillage into corn stubble
—□—: no tillage into corn mulch
Arrow indicates insecticidal treatment.

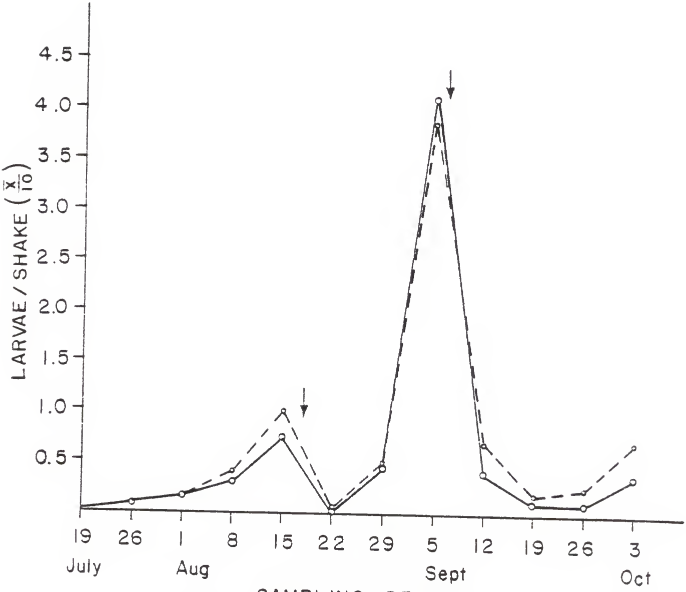


Figure 4. Average numbers of small (up to 2.5 cm) velvetbean caterpillars, Anticarsia gemmatilis, collected by the plant shaking method from no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1978. Averages of eight shakes per treatment.

——: no tillage into oat stubble
----: conventional tillage
Arrow indicates insecticidal treatment.

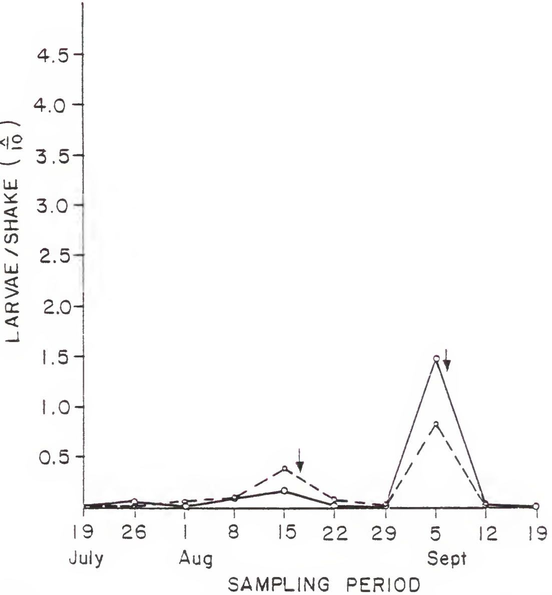


Figure 5. Average numbers of large (over 2.5 cm) velvetbean caterpillars, *Anticarsia gemmatilis*, collected by the plant shaking method from no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1978. Averages of eight shakes per treatment.

——: no tillage into oat stubble
----: conventional tillage
Arrow indicates insecticidal treatment.

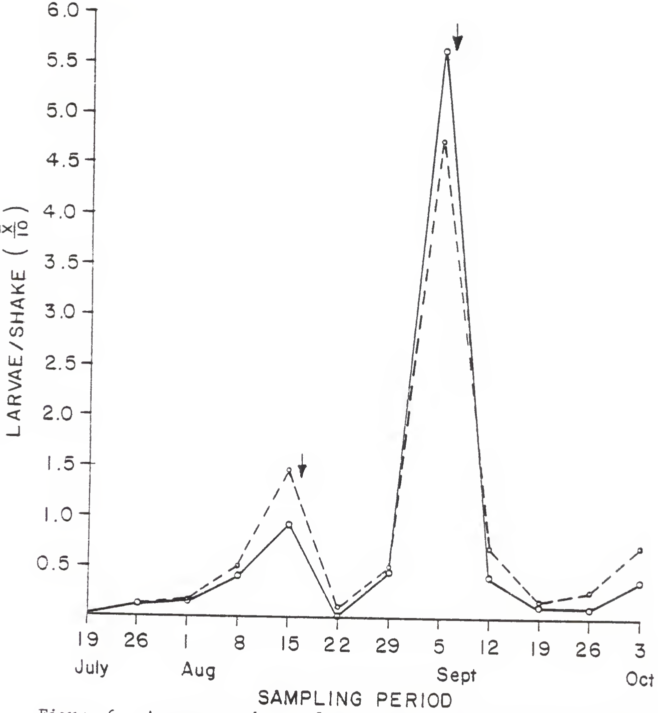


Figure 6. Average numbers of velvetbean caterpillars, *Anticarsia gemmatilis*, collected by the plant shaking method from no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1978. Average of eight shakes per treatment.

——: no tillage into oat stubble
----: conventional tillage
Arrow indicates insecticidal treatment.

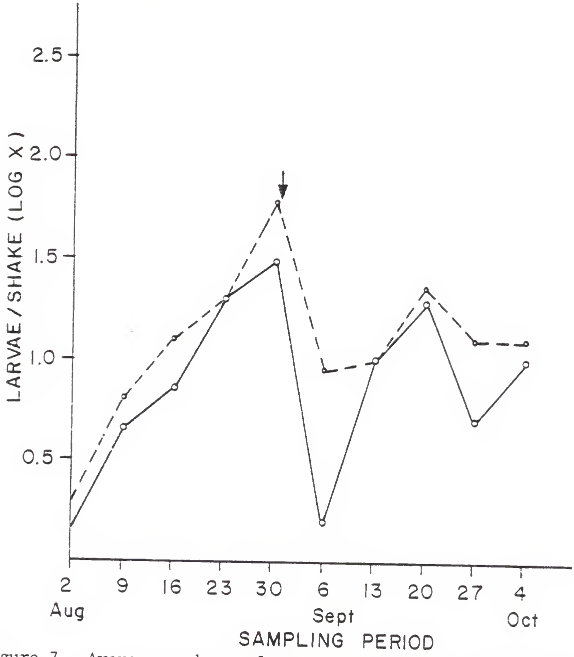


Figure 7. Average numbers of small (up to 1.5 cm) velvetbean caterpillars, Anticarsia gemmatilis, collected by the plant shaking method from no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1979. Averages of four shakes per treatment.

——: no tillage into oat stubble
----: conventional tillage
Arrow indicates insecticidal treatment.

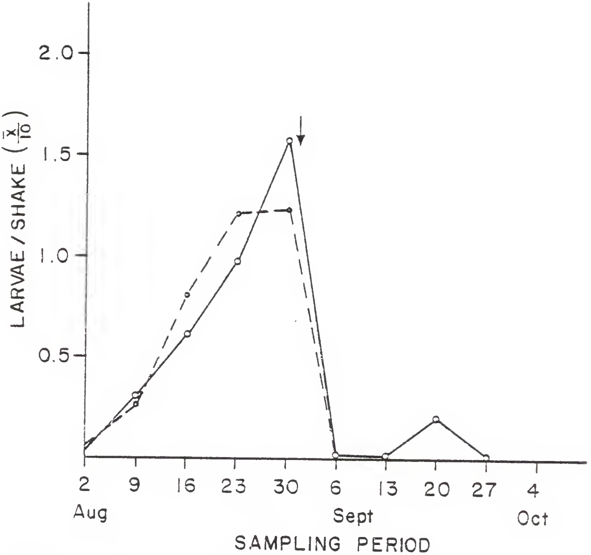


Figure 8. Average numbers of medium (1.6 - 2.5 cm) and large (over 2.5 cm) velvetbean caterpillars, Anticarsia gemmatilis, collected by the plant shaking method from no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1979. Averages of four shakes per treatment.

——: no tillage into oat stubble
----: conventional tillage
Arrow indicates insecticidal treatment.

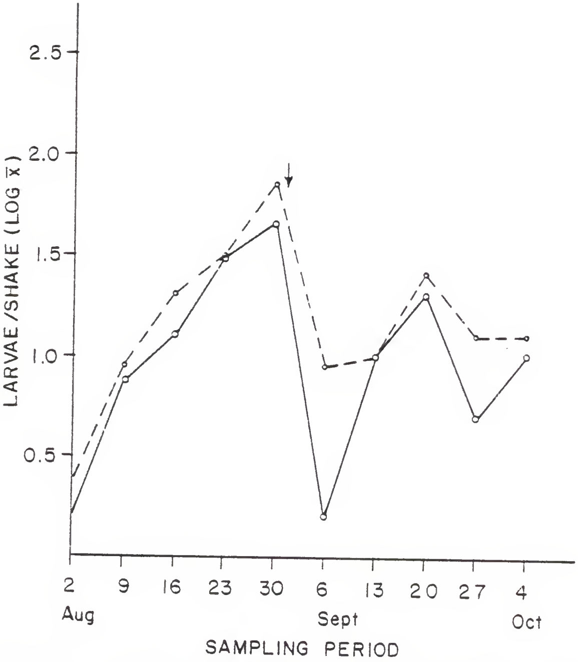


Figure 9. Average numbers of velvetbean caterpillars, Anticarsia gemmatilis, collected by the plant shaking method from no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1979. Average of four shakes per treatment.

——: no tillage into oat stubble
----: conventional tillage
Arrow indicates insecticidal treatment.

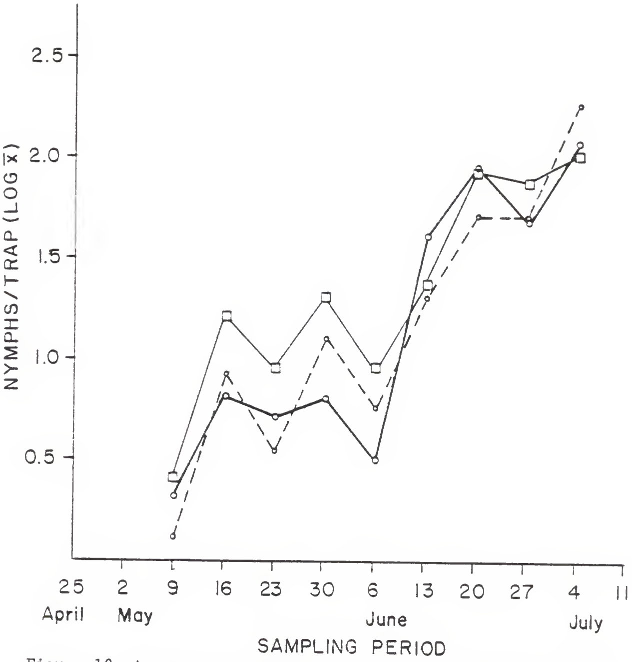


Figure 10. Average trap-week collections of Labidura riparia nymphs from no-tillage and conventional tillage "Cobb" soybeans at Williston, Levy Co., Fla., April - July, 1978. Four pitfall traps were placed in each treatment.

——: conventional tillage
----: no tillage into rye stubble
—□—: no tillage into rye mulch

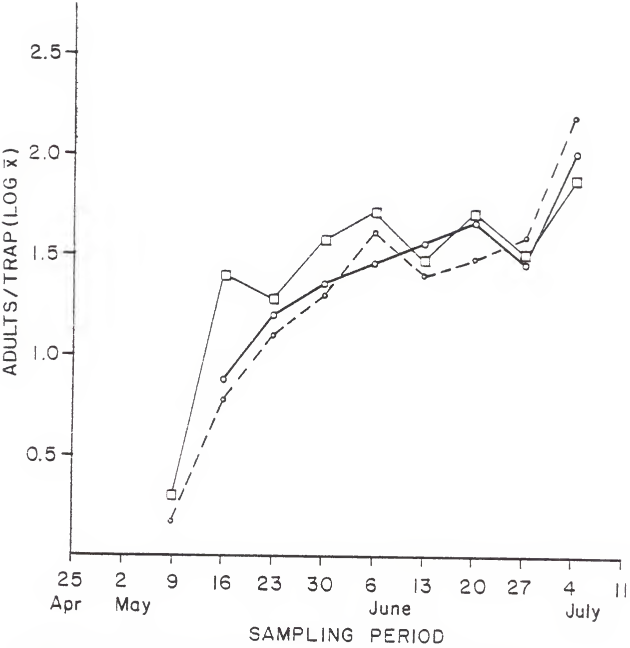


Figure 11. Average trap-week collections of Labidura riparia adults from no-tillage and conventional tillage "Cobb" soybeans at Williston, Levy Co., Fla., April - July, 1978. Four pitfall traps were placed in each treatment.

——: conventional tillage
----: no tillage into rye stubble
—□—: no tillage into rye mulch

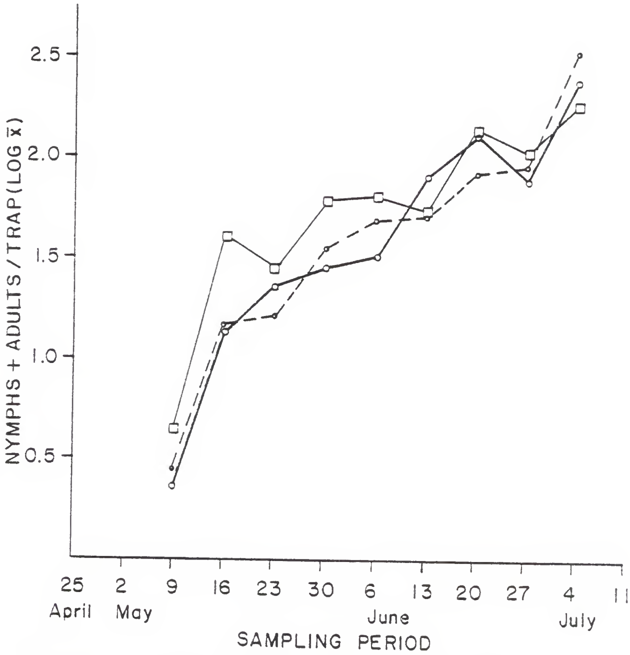


Figure 12. Average trap-week collections of Labidura riparia (nymphs + adults) from no-tillage and conventional tillage "Cobb" soybeans at Williston, Levy, Co., Fla., April - July, 1978. Four pitfall traps were set in each treatment.

——: conventional tillage
----: no tillage into rye stubble
—□—: no tillage into rye mulch

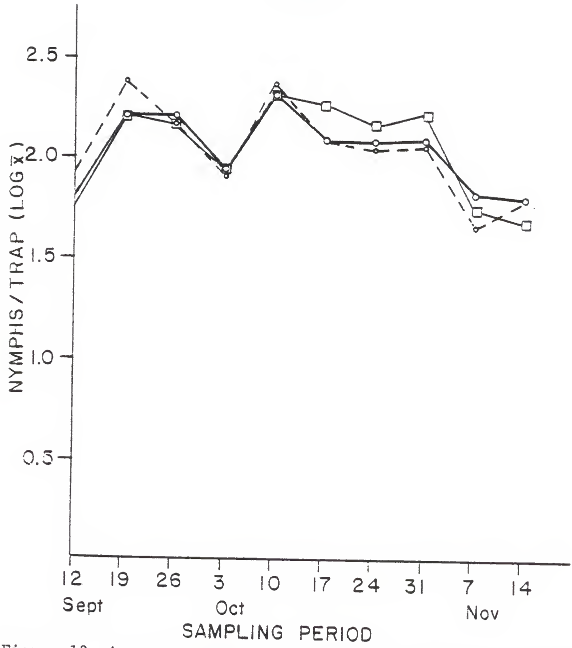


Figure 13. Average trap-week collections of _Labidura riparia_ nymphs from no-tillage and conventional tillage "Cobb" soybeans at Williston, Levy Co., Fla., September - November, 1978. Averages of four traps per treatment.

——: conventional tillage
----: no tillage into corn stubble (after rye)
—□—: no tillage into corn mulch (after rye)

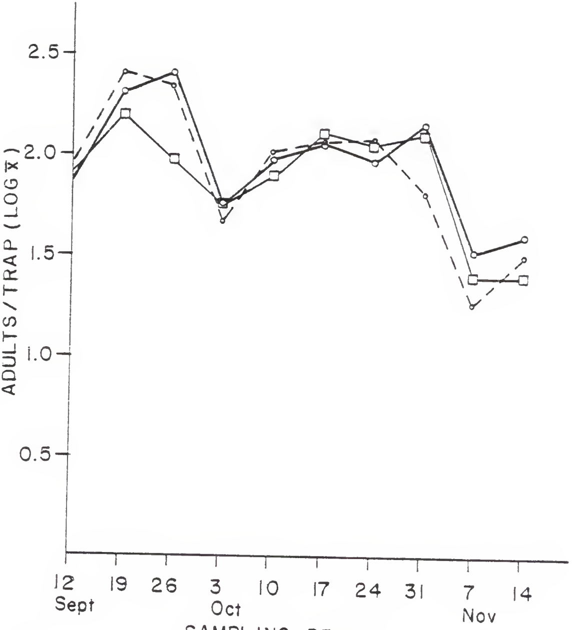


Figure 14. Average trap-week collections of <u>Labidura riparia</u> adults from no-tillage and conventional tillage "Cobb" soybeans at Williston, Levy Co., Fla., September - November, 1978. Averages of four traps per treatment.

——: conventional tillage
----: no tillage into corn stubble (after rye)
—□—: no tillage into corn mulch (after rye)

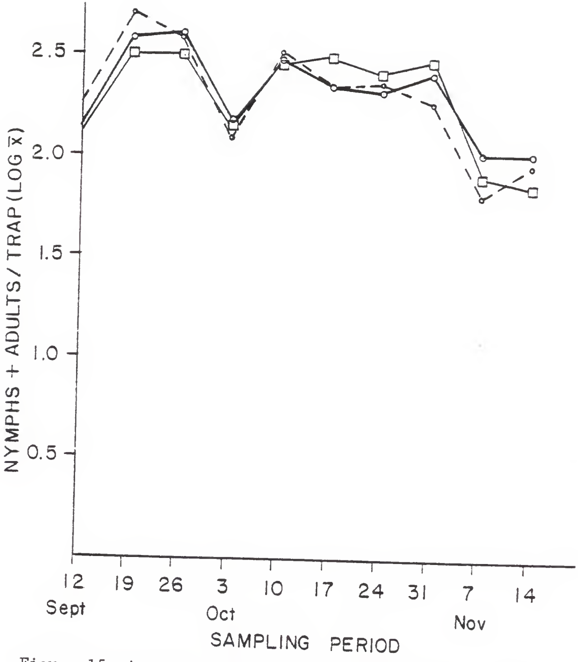


Figure 15. Average trap-week collections of Labidura riparia nymphs and adults from no-tillage and conventional tillage "Cobb" soybeans at Williston, Levy Co., Fla., September - November, 1978. Averages of four traps per treatment.

——: conventional tillage
----: no tillage into corn stubble (after rye)
—□—: no tillage into corn mulch (after rye)

Figure 16. Weekly activity of *Labidura riparia* nymphs monitored by pitfall traps in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1978. Four traps were placed in each treatment.

——: no tillage into oat stubble
----: conventional tillage

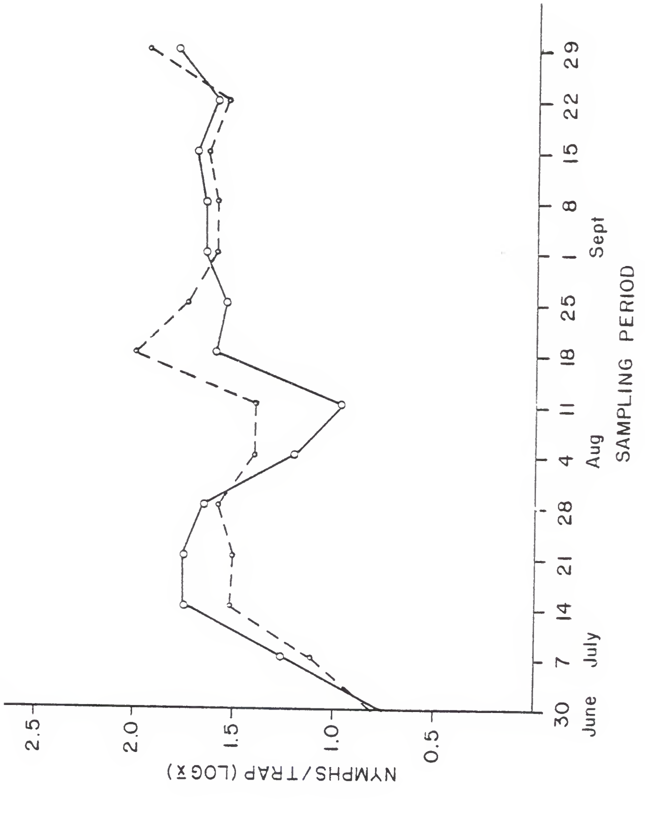

NYMPHS/TRAP (LOG x̄)
2.5
2.0
1.5
1.0
0.5
30
June
7
July
14
21
28
4
Aug
11
18
25
1
Sept
8
15
22
29
SAMPLING PERIOD

Figure 17. Weekly activity of *Labidura riparia* adults monitored by pitfall traps in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1978. Four traps were placed in each treatment.

———: no tillage into oat stubble
----: conventional tillage

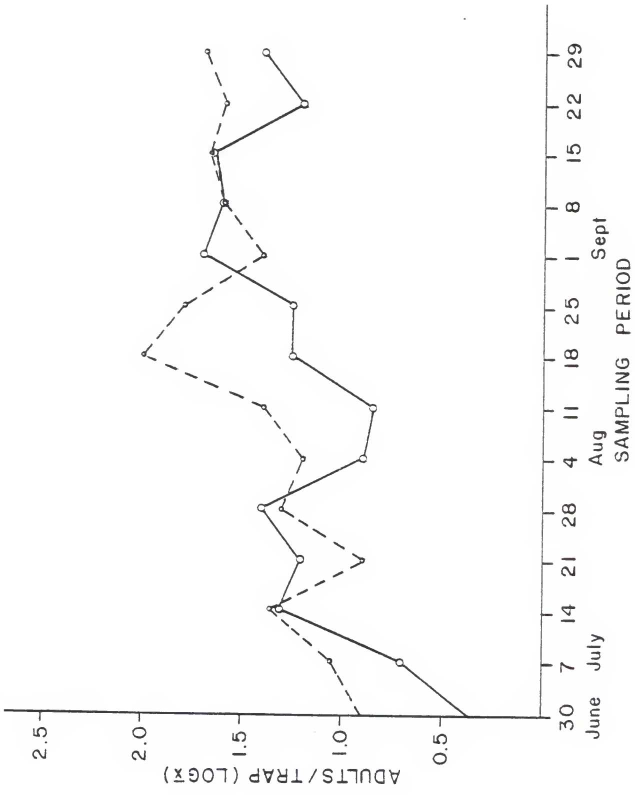

ADULTS / TRAP (LOG x̄)
0.5
1.0
1.5
2.0
2.5
30 June
7 July
14
21
28
4 Aug
11
18
25
1 Sept
8
15
22
29
SAMPLING PERIOD

Figure 18. Weekly activity of *Labidura riparia* (nymphs + adults) monitored by pitfall traps in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1978. Four traps were placed in each treatment.

——: no tillage into oat stubble
----: conventional tillate

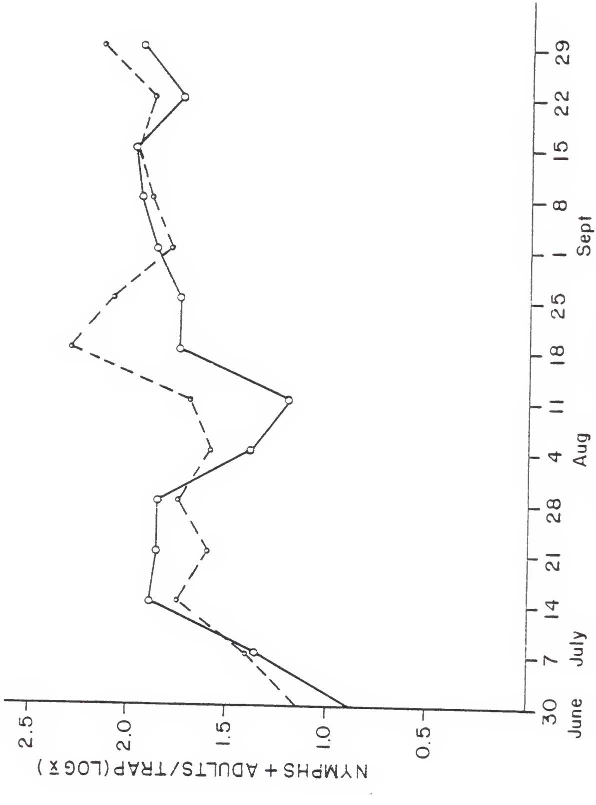

NYMPHS + ADULTS/TRAP (LOG x̄)
2.5
2.0
1.5
1.0
0.5
30
7
14
21
28
4
11
18
25
1
8
15
22
29
June
July
Aug
Sept
SAMPLING PERIOD

Figure 19. Weekly activity of *Labidura riparia* nymphs monitored by pitfall traps (four in each treatment) in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1979.

——: no tillage into oat stubble
----: conventional tillage

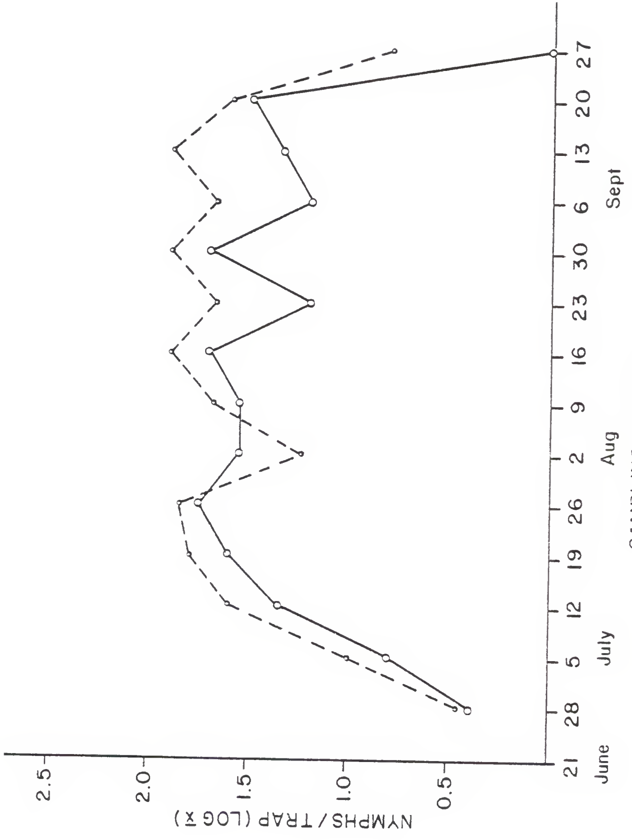

NYMPHS / TRAP (LOG x̄)
0.5
1.0
1.5
2.0
2.5
SAMPLING PERIOD
21
28
5
12
19
26
2
9
16
23
30
6
13
20
27
June
July
Aug
Sept

Figure 20. Weekly activity of *Labidura riparia* adults monitored by pitfall traps (four in each treatment) in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1979.

——: no tillage into oat stubble
----: conventional tillage

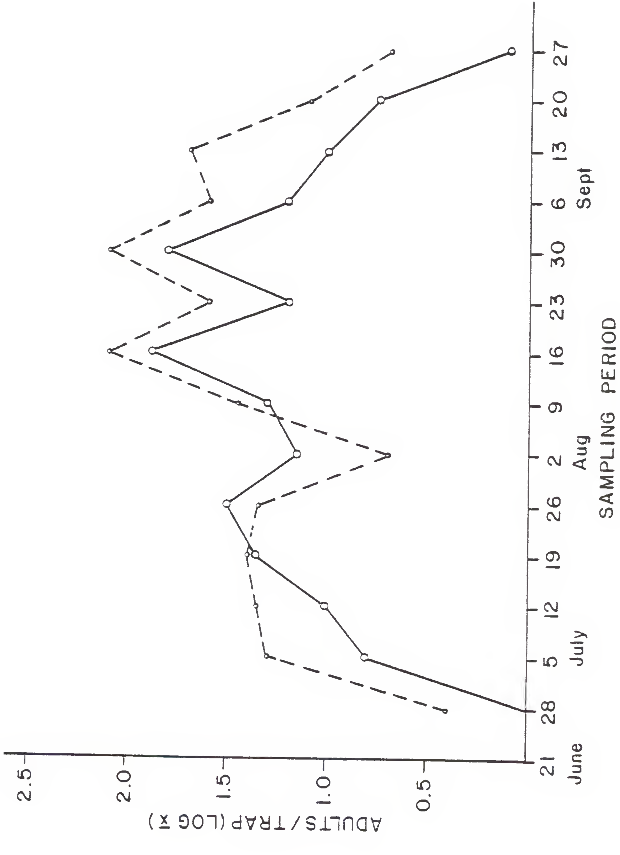
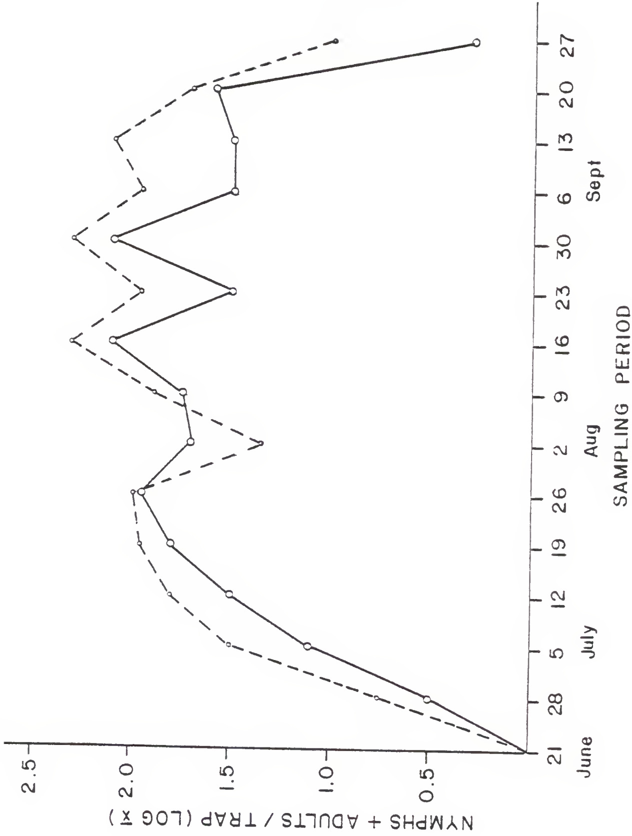

ADULTS / TRAP (LOG x̄)
2.5
2.0
1.5
1.0
0.5
SAMPLING PERIOD
June
21
28
July
5
12
19
26
Aug
2
9
16
23
30
Sept
6
13
20
27

Figure 21. Weekly activity of *Labidura riparia* nymphs and adults monitored by pitfall traps (four in each treatment) in no-tillage and conventional tillage "Cobb" soybeans at Green Acres, Alachua Co., Fla., 1979.

——: no tillage into oat stubble
----: conventional tillage


NYMPHS + ADULTS / TRAP (LOG x̄)
2.5
2.0
1.5
1.0
0.5
21
June
28
5
July
12
19
26
2
Aug
9
16
23
30
6
Sept
13
20
27
SAMPLING PERIOD

CHAPTER III

CORN CROP SYSTEMS

Materials and Methods

Cultural Practices

Vetch stubble experiment. Experiments on the effect of no tillage practice on insects in corn crop systems were conducted in two different fields at Green Acres. One field will be referred to as the vetch stubble experiment and the other as the oat stubble experiment. The vetch stubble experiment was run in a 92-m-long field divided into eight plots and previously planted to "Hairy vetch" (*Vicia villosa* Roth). Four tillage treatments were compared in this experiment, namely no tillage into vetch stubble, no tillage plus in-row subsoil into vetch stubble, conventional tillage (vetch plowed under), and conventional tillage plus in-row subsoil. Each treatment was replicated four times in a randomized complete block design.

The soil in the conventional tillage plots was prepared with a moldboard plow (April 9, 1978) and a rototiller (April 16, 1978), with vetch plowed under as green manure. In no-tillage treatments corn was seeded into the residues of the vetch. On April 19, 1978, all the plots were planted

(using the Super-Seeder already mentioned) with "DeKalb XL 78A" corn in rows 76 cm apart. Paraquat (0.42 kg a.i./ha) was used at planting, and 2,4-D (0.28 kg a.i./ha) and atrazine (2.24 kg a.i./ha) after emergence, for weed control. The entire field was fertilized at planting with 0-7.92-29.88 (N,P,K) at the rate of 448 kg/ha. Additional applications of N (28 kg/ha) were made on April 22 and June 10, 1978. During the planting operation, the plots were treated with carbofuran at the rate of 2.24 kg a.i./ha.

This experiment was repeated in the 1979 cropping season with the same cultural practices, except that no insecticide was used as soil treatment. The soil was prepared in conventional tillage plots on March 30, 1979, and corn (same hybrid) was planted on April 6, 1979.

Wheat stubble experiment. The effect of the no tillage was also determined in corn seeded into wheat ("Holly") stubble. The field (same size as in the vetch experiment) was divided into eight plots in which the same tillage treatments as above were displayed in a randomized complete block design. The soil in the conventional tillage treatments was plowed and disked twice on June 2, 1978. On June 3, all the plots were planted with "DeKalb XL 78A" corn in 76 cm rows. The plots were treated with alachlor (1,12 kg a.i./ha) and atrazine (1.68 kg a.i./ha) for weed control. In addition to these two herbicides, no-tillage plots were treated with paraquat (0.42 kg a.i./ha, plus

Ortho X-77 surfactant) on June 3, 1978. All the treatment received 672.60 kg/ha of 5-4.4-12.5 (N,P,K) on June 3. An additional application of 56 kg/ha of N was made in all the plots on June 12, 1978. Half of the rows in each plot were treated with carbofuran (2.24 kg a.i./ha) during the planting operation. The other rows were not treated.

In 1979 the experiment was repeated without the carbofuran application, but all other practices were the same as in the 1978 season. Conventional tillage plots were prepared on June 4, and corn was planted on June 12, 1979.

Estimation of Insect Damage and Arthropod Populations

Soil arthropods. Damage to corn by soil insects was assessed by randomly selecting two rows per replication every week and counting the number of damaged plants. Numbers of stunted, wilted or dead plants, characteristic of the lesser cornstalk borer damage, as well as numbers of cut, chewed plants (cutworms), were recorded. In the wheat experiment, the total number of plants in the two selected rows was recorded along with damaged plants in order to estimate the percentages of damaged plants.

Populations of soil-inhabiting pest insects and arthropod predators were monitored by means of pitfall traps as described in the soybean section above. One trap was placed in the middle row of each replication when corn was in stage 0.5 or stage 1 (Hanway, 1966). The traps were kept in the field until corn was mature or until ears were dry.

Above-ground insects. Fall armyworm and corn earworm damage was estimated by weekly visual observations. Two rows were randomly chosen in each replication, and 15 consecutive plants were carefully observed in each row. A total of 120 plants were thus examined weekly for each treatment. The number of damaged plants (showing any damage level, but whorl not destroyed) and the number of plants with completely damaged whorl was recorded. When corn started tasseling (Stages 4 and 5, Hanway, 1966), damage to the tassel was determined in the wheat stubble experiment by recording the number of plants having at least half of the tassel destroyed.

After ear shoots appeared, observations were no longer made on the foliage, but only on ears. The combined damage of *Spodoptera frugiperda* (J. E. Smith) and *Heliothis zea* (Boddie) to corn ears was estimated by counting and recording the number of damaged ears on 30 plants randomly selected from two rows in each replication (120 plants per treatment). Two other rows were randomly chosen in each plot and the number of damaged ears was recorded. Damage to ears was also assessed at the harvest time. Each replication (plot) was crossed diagonally and eight ears were collected. A total of 32 ears were thus collected from each treatment. The ears were placed in paper bags and brought into the laboratory where the number of damaged ears (showing any outside damage level) and the number of ears with a damaged area extending to one or more centimeters within the kernel rows were recorded.

Results and Discussion

Above-Ground Insects

Vetch stubble experiment. Damage to corn foliage and ears caused by *Spodoptera frugiperda* and *Heliothis zea* in the 1978 vetch experiment is shown in Table 21. The percent of plants with damaged foliage was 24.59 in the no tillage and 30.83 in the conventional tillage; that of ear damage was 50.78 in the conventional tillage plus in-row subsoil and 44.32 in the no tillage. The difference between treatments, however, were not significant. Damage on ears was higher than on the foliage; 44% of the ears in the no till and 43% in the conventional tillage were damaged. Weekly damage levels on the foliage and ears are shown in Figure 22.

The data were analyzed on a weekly basis, in addition to the overall analysis, to detect any tillage effect throughout the cropping season. Such an effect may disappear as field conditions change during the season. No significant differences were found between treatments on a weekly basis for foliage damage (Fig. 22), but the percent of infested ears was significantly higher in the no-tillage corn than in the conventional tillage corn during the week when corn plants were in the dent-physiologic maturity stage (Hanway, 1966).

Infestations were comparatively low during the second season. The 1979 data from the vetch experiment showed

that no-tillage practice did not significantly affect *S. frugiperda* and *H. zea* damage to field corn foliage and ears, as compared to the conventional tillage corn (Table 22). The weekly analysis of the data failed to show any single week during which the difference between treatment means was significant. Infestation levels in the no till were 0.38 infested plants and 2.75 infested ears per row-week; percent infestation was 1.5% infested plants and 10.6% infested ears. In the conventional tillage an average of 0.65 plants and 1.97 ears were infested in each row every week. In terms of percent, 1.5% of the plants and 5.4% of the ears were infested.

Wheat stubble experiment. Corn in this experiment was late planted in both 1978 and 1979, and *Spodoptera-Heliothis* infestations were very high. Damage levels were assessed on leaves, tassels, and ears in 1978. Table 23 contains the results. The average percent of plants with infested foliage (but whorl not destroyed) and that of plants with destroyed whorl were statistically the same in all the treatments. Damage levels on tassel were very high and appeared to be higher in the conventional tillage plots than in the no-tillage plots, but the analysis of the data did not detect any significant differences among treatments. Differences between treatments also were not significant for damage to ears. About 95% of the plants observed in no till and 93% in conventional

till plots had a damaged whorl. Plant regrowth occurred, but the stand reduction remained very high. Ears were also very severely damaged in the late planted corn. More than 86% of the ears in the no till, and 82% in the conventional till plots had Spodoptera-Heliothis damage.

Data collected in the second (1979) season from the wheat experiment are in Table 24. Damage to the foliage was estimated as average numbers of damaged plants per row, percent of damaged plants calculated on a row basis, and percent of infested plants calculated on the basis of 120 plants observed per treatment and per week. The analysis of the data showed that, whatever the method used to estimate the damage, no-tillage cropping did not have a significant impact on fall armyworm and corn earworm infestations as compared to the conventional tillage (Table 24).

The fall armyworm and corn earworm damage to ears assessed at the harvest time is shown in Tables 25 and 26, respectively for the vetch stubble and wheat stubble experiments. No significant differences were detected between treatments in the two experiments.

No-till practice into vetch and wheat stubble did not, in this study, significantly affect S. frugiperda and H. zea infestations on field corn during the two years of observation. Some above-ground insects such as the armyworm (Pseudaletia unipuncta) are reported to cause more severe damage to no-till corn than to the conventionally

tilled corn (Musick and Suttle, 1973). These insects are generally attracted by, and oviposit in, grassy areas of the no-till corn. The fall armyworm females usually oviposit on green plants, and corn earworm females on larval host plants (Metcalf et al., 1962). Crop residues in no-tillage plots apparently did not attract female moths to oviposit in these plots. If such an attraction and concentration had occurred, more infested plants would have been observed in no-till plots, especially during the first weeks. Weekly, as well as overall analysis of the data failed to show any significant preference by female moths for the no-till corn.

Conceivably, pest populations might have been higher in the no till than in the conventional tillage and subsequently reduced by higher predator populations in the no-till plots. However, results obtained on ground predators showed that predator numbers were lower in the no-till plots than in conventional plots. It is believed that female moths indiscriminately laid eggs on corn plants in all the plots because no-till plots did not provide better above-ground conditions than those in the conventional tillage plots.

Soil Insect Pests

Wireworms. Two species of wireworms (Elateridae), *Conoderus amplicollis* (Gyll.) and *C. falli* Lane, were

collected in large numbers from the vetch and wheat stubble expreiments. Of the two species, *C. amplicollis* was more abundant than *C. falli* in both experiments. *Conoderus* spp. are not important pests on corn in Florida, but their numbers were recorded in order to detect any tillage effect.

Data collected in 1979 from both experiments are shown in Table 27. Statistical analysis of data showed that no-tillage cropping, as well as in-row subsoil did not affect significantly populations of *Conoderus* spp. as compared to the conventional tillage. Wireworm populations were highest toward the end of the crop season; at the beginning of the season, when corn could be in the most susceptible (relative to these pests) stage, wireworms were in low numbers.

Lesser cornstalk borer in vetch stubble. The average numbers of damaged plants recorded from the vetch experiment in 1978 and 1979 are shown in Table 28. Lesser cornstalk borer infestations were relatively low in both seasons. In the 1978 cropping season, infestations were significantly (P=0.05) lower in the no-tillage corn than in the conventionally tilled corn. The weekly average number of damaged plants per row was 0.13 and 1.33, respectively in the no-till and conventional till corn (Table 28). The results also showed that subsoiling into the furrows did not significantly affect infestation levels in either no-tillage or the conventional tillage treatments.

Table 28 shows lesser cornstalk borer infestations recorded from the vetch stubble experiment in 1979. No tillage did not affect E. lignosellus infestations in corn during the 1979 season. No significant differences were found between treatment means. Average numbers of damaged plants per row were 0.94 and 0.81, respectively, in no-till and conventional till corn.

Lesser cornstalk borer in wheat stubble. Corn followed wheat in this experiment and was seeded into wheat stubble in no-till plots. In addition to counting only the number of damaged plants as in the vetch stubble experiment, the total number of corn plants per row were recorded along with damaged plants. Damage was thus estimated as number of damaged plants per row and as percentage of damaged plants. Tables 29 and 30 show the results obtained, respectively, in 1978 and 1979. Lesser cornstalk borer infestations, estimated as percent of damaged seedlings or number of damaged seedlings per row, were significantly (P=0.05) lower in the no-till corn than in the conventional tillage corn (Table 29). The average number of damaged corn seedlings was about three times higher in the conventional till than in the no-till treatment. About 1.5% and 3.5% of the plants observed were damaged in no-till and conventional till plots, respectively. In-row subsoiling at planting significantly increased E. lignosellus damage in the no-tillage plots, but not in the conventional tillage plots.

When this experiment was repeated in the 1979 season, no-tillage cropping did not significantly affect infestation levels (Table 30), although the percentage of damaged plants and the average number of infested plants per row appeared to be slightly higher in conventionally tilled plots than in untilled plots. In general, infestations were higher during this season than in the previous season. The average damage level for the whole field was only 2.89% of the plants infested in 1978, but 8.20% in 1979.

The results collected during the two years indicated that E. lignosellus infestations were higher in the late planted corn (wheat stubble experiment) than in the early planted corn. The entire field in the vetch stubble experiment was treated with carbofuran at planting in 1978. It was not possible, therefore, to determine whether the low infestations observed in this field were due to the insecticide or to the early planting (as reported by Leuck, 1966). Infestations might also have been naturally low during that season. Half of the rows in the wheat stubble experiment were treated, at planting, with carbofuran in 1978. No significant differences in numbers of damaged plants were found between treated and untreated rows within a same tillage system. Carbofuran apparently did not influence lesser cornstalk borer infestations. This may be because infestation levels were naturally low during the season.

No-tillage practice failed to significantly affect lesser cornstalk borer infestations in the 1979 cropping season when corn was seeded into vetch or wheat stubble. In the 1978 season, this practice significantly reduced E. lignosellus infestations in both experiments. These results agreed with those reported by All and Gallaher (1977) and All et al. (1979). They found that lesser cornstalk borer infestations were greatly reduced in no-tillage corn as compared to corn planted in conventionally tilled blocks. Crop residues left on the ground in no-till systems were found to be the most important factor contributing to these low infestations (Cheshire et al., 1977; Cheshire and All, 1978). Crop residues reduce infestations by either providing food to the saprophagous larvae or by disrupting the feeding behavior of the larvae through odor or mechanical shielding of the host plants.

Cutworms in vetch and wheat stubble. During the 1978 season very few granulate cutworms [Feltia subterranea (Fab.)] were found in the traps in the vetch stubble and wheat stubble experiments. One cutworm was collected in 1979 in the wheat experiment. Cutworm populations in the vetch experiment, however, were high in the 1979 season. The results recorded during that season are in Table 31. Numbers of cutworms were significantly (P=0.05) higher in the no-till corn than in the conventional till corn. The no tillage plus subsoil also harbored more

cutworms than any of the conventional tillage treatments. The weekly average numbers of cutworms per trap were 10.0 and 2.1, respectively, in the no-tillage and conventional tillage plots. Subsoiling did not significantly increase cutworm numbers within a same tillage system, although the average number in no tillage plus subsoil was twice higher than in the no tillage without subsoil (Table 31).

Although cutworm populations were high in the no-till plots, damage to corn seedlings was very low. Total numbers of damaged plants recorded were one, zero, three and one, respectively, from the conventional tillage, conventional tillage plus subsoil, no tillage, and no tillage plus subsoil. The corresponding plant population was estimated in each treatment plot by randomly selecting three rows per replication and counting the total number of plants. The average numbers of plants per row were 26.5, 35.3, 38.0, and 38.0, for no till, no till plus subsoil, conventional tillage, and conventional tillage plus subsoil. Damage levels might have been underestimated because some plants might have been infested but did not fall down or were not completely cut. No noticeable cutworm damage, however, was observed throughout the field.

It is not clear whether low cutworm numbers in 1978 were due to the carbofuran treatment of the soil. Cutworms are known to vary greatly in numbers from one year to another (Metcalf et al., 1962); populations are believed

to have been naturally low in the area in 1978, although the insecticide might have had some effect. Cutworms generally overwinter in the soil, under trash or clumps of grasses, and female moths emerge from the soil in the spring and oviposit on grasses and other plants. No-tillage systems provide an adequate environment for F. subterranea development because of the trash left on the ground and the lack of soil tillage to destroy the larvae and pupae.

That cutworms cause more severe damage to no-tillage corn than to the conventional tillage corn has already been documented (Musick, 1970b). It is not known, however, why these relatively high cutworm populations caused practically no damage to corn seedlings in this experiment. The same mechanism as that reported by Cheshire and All (1978) for the lesser cornstalk borer may be involved here. Crop residues in the no-till plots might have served as food for the larvae, and prevented them from easily locating corn plants.

Soil-Inhabiting Predators

Ground dwelling spiders. The activity of ground dwelling spiders was monitored in corn in 1978 and 1979 in the vetch stubble experiment and in 1979 in wheat stubble. Statistical analyses of data did not detect any significant differences between the treatments. The weekly average numbers were 1.30, 1.19, 1.28 and 1.47 spiders per trap

in no tillage, no tillage plus in-row subsoil, conventional tillage and conventional tillage plus in-row subsoil, respectively.

When the data were analyzed on a weekly basis, however, they revealed significant differences among treatments during the third, seventh and eighth weeks of the sampling period. During the third week, the activity of the spiders was significantly (P=0.01) higher in the no tillage than in the conventional tillage. The average numbers were 2.5 and 0.25 spiders per trap, respectively in the no-tillage corn and conventional tillage corn. The activity of the spiders was significantly (P=0.05) reduced in no-tillage plots during the seventh week but increased during the eighth week.

In 1979 populations of ground spiders were very high as compared to the 1978 crop season. The weekly averages were 5.68, 7.66, 7.02 and 7.04 spiders per trap, respectively, in no till, no till plus in-row subsoil, conventional tillage and conventional tillage plus in-row subsoil. No significant differences were found between these means. The average numbers of spiders collected from the wheat stubble experiment were 2.96, 3.50, 3.00 and 3.50 spiders per trap, respectively in no tillage, no tillage plus in-row subsoil, conventional tillage and conventional tillage plus in-row subsoil. Spider populations were not affected by the tillage method in corn crop systems.

Carabid beetles. Species and numbers of carabid beetles collected in pitfall traps from the vetch stubble experiment are in Tables 32 and 33, respectively for the 1978 and 1979 crop seasons. Five species were recorded in the 1978 experiment, and all, except Galerita lecontei (Dejean), were classified as very rare species, according to Rivard's (1964) scale: "Very rare, 10 specimens or less; Rare, 11 to 50; Common, 51 to 200; Abundant, over 200". Galerita lecontei was a rare species; 48.15% of all the carabid predators collected were G. lecontei with 69.23% of the specimens being collected from the conventional tillage plus in-row subsoil. None of the G. lecontei specimens was recorded from the no tillage, and only one specimen was caught from the no tillage plus in-row subsoil (Table 32).

In 1979, the number and species of carabids increased, and 12 different species were recorded (Table 33). Only G. lecontei, Harpalus pennsylvanicus DeGeer, and Selenophorus palliatus Fab. were rare species; the others were very rare. About 47% of the carabids were collected from the conventional tillage plus in-row subsoil; 30% were recorded from the conventional tillage without subsoil. No till and no till with subsoil harbored respectively 11.96 and 9.78% of the carabids collected.

The number of carabid beetles in the wheat experiment was relatively low during the two cropping seasons. Twelve

specimens belonging to five species were recorded in 1978 (Table 34). All the species were very rare, and S. palliatus accounted for about 50% of all the species collected. Most of the carabids (42%) were collected from the no-tillage corn. Selenophorus was also the most predominant species in the 1979 season, but the activity of the beetles was monitored for four weeks only in this experiment in 1979.

One species, G. lecontei, was active throughout the season until the corn was mature. The highest numbers were recorded two to three weeks after ears appeared. At this stage, a relatively high percent of the ears were already infested by the Heliothis-Spodoptera complex. Selenophorus palliatus was collected most often toward the end of the season. Pasimachus spp. were more active during the first five weeks of the sampling period, i.e. six to seven weeks after corn was planted. The catches for other species were very erratic. These results agreed with the report by Galvez (1979) who found that the activity of the carabid beetles in corn at Green Acres was inconsistent during the entire study period, and that carabid fauna generally was either rare or very rare. Carabid populations were in such low numbers, and appeared so infrequently that it is not believed that these predators played any important role in regulating pest populations.

With respect to the tillage systems, the results indicated a preference by the carabids to colonize conventional

tillage plots. Since pest populations in the conventional tillage plots were not significantly higher than those in the no-till plots, it may be assumed that the beetles were attracted by the more favorable edaphic conditions in these plots rather than by pest populations. The absence of carabid larvae (only four, not identified, were caught) in the traps might indicate that most of the carabids were originating from the neighboring wooded area or fields.

Striped earwig. Data on the foraging activity of *L. riparia* are presented in graphs and analyzed on a weekly basis (in addition to the overall analysis) in order to show the effect of the tillage practice throughout the cropping season. Figure 23 shows the weekly activity of the earwig (all stages combined) in the vetch stubble experiment in 1978. The overall analysis of the data indicated that no-tillage practice, as compared to the conventional tillage, did not significantly affect the populations of earwigs.

The weekly analysis showed that during the second week of the sampling period (about four weeks after corn was planted), the *Labidura* population was significantly higher in the conventional tillage than in the no-tillage corn. During the third week a significant difference between treatments was found only for the nymphal population (not shown separately on the graph) which was higher in the conventional tillage than in the no-tillage corn.

The results obtained from the wheat stubble experiment in both the 1978 and 1979 seasons are shown in Figures 25 and 26, respectively. In 1978, nymphal and adult Labidura populations remained statistically the same in the no-tillage and conventional tillage corn throughout the sampling period, except during the eighth week when the nymphal population was significantly (P=0.05) higher in the conventional tillage than in the no tillage.

In the 1979 season (Figure 26), the conventional tillage corn harbored significantly more earwig nymphs during the first two weeks of the sampling period than did the no-tillage corn. During the fifth week, the adult population was higher in the conventional tillage than in the no-tillage corn; at the end of the sampling period, the total (nymphs and adults) population was significantly (P=0.01) higher in the conventional tillage plots than in the no-tillage plots. The difference between treatment means (no till vs. conventional till) were highly significant (P=0.01) for both the nymphal and the adult populations.

Data collected during the two years from silage corn planted into either vetch or wheat stubble indicated that the no-tillage corn generally harbored lower L. riparia populations than the conventional tillage corn. This trend was more apparent for the nymphal population than for the adult population. In fact, in most of the experiments where no-tillage farming significantly affected the earwig populations, numbers of nymphs were lower in no-tillage plots than in the conventional tillage ones while the

numbers of adults remained statistically the same in all the plots. Lower nymphal populations in untilled plots may be an indication that adult earwigs preferentially moved to the tilled plots to breed (to oviposit) while they indiscriminately spread into all the treatment plots for foraging activity.

Table 21. Foliage and ear damage caused by the fall armyworm, <u>Spodoptera frugiperda</u> (J. E. Smith), and the corn earworm, <u>Heliothis zea</u> (Boddie), in no-tillage and conventional tillage corn at Green Acres, Alachua Co., Fla., 1978. Numbers are averages of 120 plants per treatment (each week) for four weeks for foliage and three weeks for ears.

Treatment	% infestation*	
	Foliage	Ears
No tillage into vetch stubble	24.59	44.32
No tillage plus in-row subsoil into vetch stubble	37.46	38.40
Conventional tillage	30.83	43.25
Conventional tillage plus in-row subsoil	22.71	50.78

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 22. Damage caused by the fall armyworm, *Spodoptera frungiperda*, and corn earworm, *Heliothis zea*, to no-tillage and conventional tillage field corn at Green Acres, Alachua Co., Fla., 1979. Numbers are averages of 120 plants per treatment (each week) for five weeks for foliage and four weeks for ears.

Treatment	Corn infestation*			
	Avg. No./row		% infestation	
	plants	ears	plants	ears
No tillage into vetch stubble	0.38	2.75	1.50	10.61
No tillage plus in-row subsoil into vetch stubble	0.50	3.60	2.00	14.60
Conventional tillage	0.65	1.97	1.50	5.36
Conventional tillage plus in-row subsoil	0.44	3.38	0.83	9.95

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 23. Infestations of the fall armyworm, *Spodoptera frugiperda*, and corn earworm, *Heliothis zea*, in no-tillage and conventional tillage field corn at Green Acres, Alachua Co., Fla., 1978. Average based on 120 plants per treatment per week.

Treatment	% infestation*			
		Plants with destroyed		
	Plants	Whorl	Tassel	Ears
No tillage into wheat stubble	77.50	94.58	74.16	86.86
No tillage plus in row sub-soil into wheat stubble	77.83	90.83	70.88	78.47
Conventional tillage	74.83	93.33	84.34	82.31
Conventional tillage plus in-row subsoil	76.17	94.58	83.17	72.10

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 24. Infestations of the fall armyworm, *Spodoptera frugiperda*, and corn earworm, *Heliothis zea*, in no-tillage and conventional tillage field corn at Green Acres, Alachua Co., Fla., 1979.

Treatment	Infested plants*		
	Average No./row	% (on row basis)	% (on 120 plant basis)
No tillage into wheat stubble	31.42	68.94	91.67
No tillage plus in-row subsoil into wheat stubble	35.25	71.80	92.09
Conventional tillage	26.96	60.30	87.50
Conventional tillage plus in-row subsoil	30.71	64.54	88.75

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 25. Fall armyworm and corn earworm damage to the conventional and no-tillage corn assessed at the harvest time at Green Acres, Alachua Co., Fla., 1979. Thirty-two ears collected per treatment.

Treatment	Damaged Ears*		Ears with Damaged Kernels*	
	No.	%**	No.	%**
No tillage into vetch stubble	20	62.50	9	28.12
No tillage plus in-row subsoil into vetch stubble	12	37.50	4	12.50
Conventional tillage	15	46.87	6	18.75
Conventional tillage plus in-row subsoil	21	65.62	9	28.12

*Damaged ears: ears with any outside damage level. Damaged kernels: ears with a damaged area extending to one or more centimeters within the kernel rows.

**In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 26. Fall armyworm and corn earworm damage to the conventional and no-tillage corn assessed at the harvest time at Green Acres, Alachua Co., Fla., 1979. Forty ears were collected per treatment.

Treatment	Damaged Ears*		Ears with Damaged Kernels*	
	No.	%**	No.	%**
No tillage into wheat stubble	38	95.0	31	77.50
No tillage plus in-row subsoil into wheat stubble	33	82.50	27	67.50
Conventional tillage	39	97.50	34	85.0
Conventional tillage plus in-row subsoil	39	97.50	37	92.50

*Damaged ears: ears with any outside damage level. Damaged kernels: ears with a damaged area extending to one or more centimeters within the kernel rows.

**In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons not made.

Table 2.7. Number of *Conoderus amplicollis* (Gyll.) and *C. falli* Lane (Elateridae) collected in pitfall traps from conventional tillage and no-tillage field corn at Green Acres, Alachua Co., Fla., 1979. Numbers are totals and averages of nine weeks for vetch and six weeks for wheat with four traps per treatment.

Treatment	Total Number Vetch stubble	Total Number Wheat stubble	Average/trap* Vetch stubble	Average/trap* Wheat stubble
No tillage	466	150	12.94	6.25
No tillage plus in-row subsoil	368	207	10.22	8.62
Conventional tillage	389	265	10.80	11.04
Conventional tillage plus in-row subsoil	280	173	7.78	7.21

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 28. Lesser cornstalk borer, (*Elasmopalpus lignosellus* (Zeller)), infestations in no-tillage and conventional tillage field corn at Green Acres, Alachua Co., Fla., 1978 -1979. Estimation is based on eight rows per treatment examined each week for three weeks.

Treatment	Damaged plants			
	Total No.		Average No/row*	
	1978	1979	1978	1979
No tillage into vetch stubble	3	15	0.13a	0.94c
No tillage plus in-row subsoil into vetch stubble	2	13	0.08a	0.81c
Conventional tillage	32	3	1.33b	0.19c
Conventional tillage plus in-row subsoil	32	2	1.33b	0.12c

*Means in each column not followed by the same letter are significantly different at the 0.05 level by Duncan's new multiple range test.

Table 29. Infestations of the lesser cornstalk borer, *Elasmopalpus lignosellus*, in no-tillage and conventional tillage field corn at Green Acres, Alachua Co., Fla., 1978.

Treatment	No. plants observed	No. infested	Infestation* %	Infestation* Plants/row
No tillage into wheat stubble	1987	31	1.56a	0.97c
No tillage plus in-row subsoil into wheat stubble	2751	104	3.78b	3.25d
Conventional tillage	2507	88	3.51b	2.75d
Conventional tillage plus in-row subsoil	2966	80	2.70b	2.50d

*Values in each column not followed by the same letter are significantly different at the 0.05 level by Duncan's new multiple range test.

Table 30. Infestations of the lesser cornstalk borer, *Elasmopalpus lignosellus*, in no-tillage and conventional tillage field corn at Green Acres, Alachua Co., Fla., 1979.

Treatment	No. plants		Infestation*	
	Total observed	Number infested	%	Avg/row
No tillage into wheat stubble	1138	90	7.91	3.75
No tillage plus in-row subsoil into wheat stubble	1171	89	7.60	3.71
Conventional tillage	1160	109	9.40	4.54
Conventional tillage plus in-row subsoil	1140	90	7.89	3.75

*In the analysis of variance, no significant differences were detected among the means. Therefore, Duncan's comparisons were not made.

Table 31. Activity of the granulated cutworm, *Feltia subterranea* (Fab.), monitored by nonbaited pitfall traps in no-tillage and conventional tillage corn at Green Acres, Alachua Co., Fla., 1979. Numbers are totals and average of four traps per treatment for four weeks.

Treatment	Cutworm population Tot. No.	Avg./trap
No tillage into vetch stubble	160	10.0a*
No tillage plus in-row subsoil into vetch stubble	345	21.6a
Conventional tillage	34	2.1b
Conventional tillage plus in-row subsoil	5	0.3b

*Values not followed by the same letter are significantly different by Duncan's new multiple range test at the 0.05 level.

Table 32. Number and species of carabid predators collected in pitfall traps from no-tillage and conventional tillage field corn at Green Acres, Alachua Co., Fla., May - July, 1978. Numbers are totals of four traps per treatment.

Species	NVS	NVS+s	CT	CT+s	Tot.	%	Index**
<u>Calosoma</u> <u>sayi</u> Dejean	0	0	1	0	1	1.09	VR
<u>Chlaenius</u> <u>laticollis</u> Say	0	0	0	1	1	1.09	VR
<u>C</u>. <u>tomentosus</u> Say	0	0	1	0	1	1.09	VR
<u>Colliuris</u> <u>pennsylvanica</u> (L.)	0	0	2	5	7	7.61	VR
<u>Galerita</u> <u>lecontei</u> Dejean	7	2	10	16	35	38.04	R
<u>G</u>. <u>janus</u> (Fab.)	1	1	2	0	4	4.35	VR
<u>Harpalus</u> <u>caliginosus</u> Fab.	1	0	0	0	1	1.09	VR
<u>H</u>. <u>pennsylvanicus</u> DeGeer	0	3	2	9	14	15.22	R
<u>Pasimachus</u> <u>sublaevis</u> Beauv.	2	0	0	1	3	3.26	VR
<u>P</u>. <u>subsulcatus</u> Say	0	0	0	1	1	1.09	VR
<u>Scarites</u> <u>subterraneus</u> (Fab.)	0	1	0	0	1	1.09	VR
<u>Selenophorus</u> <u>palliatus</u> Fab.	0	2	10	11	23	25.00	R
Total	11	9	28	44	92		
%	11.96	9.78	30.43	47.83			

*NVS: no tillage into vetch stubble; NVS+s: No tillage plus in-row subsoil into vetch stubble; CT: conventional tillage; CT+s: conventional tillage plus in-row subsoil.

**Rivard's scale: VR: very rare; 10 specimens or less; R: rare, 11 to 50 specimens; etc.

Table 33. Numbers and species of carabid predators collected in pitfall traps from no-tillage and conventional tillage field corn at Green Acres, Alachua Co., Fla., April-July, 1979. Numbers are totals of four traps per treatment.

Species	Treatment NVS	NVS+s	CT	CT+s	Tot.	%	Index**
Calosoma sayi Dejean	0	0	1	1	2	7.4	VR
Colliuris pennsylvanica (L.)	0	1	3	0	4	14.8	VR
Galerita lecontei	0	1	3	9	13	48.1	R
Harpalus pennsylvanicus DeGeer	1	1	0	1	3	11.1	VR
Pasimachus sublaevis Beauv.	1	1	2	1	5	18.5	VR
Total	2	4	9	12	27		
%	7.4	14.8	33.3	44.4			

*NVS: no tillage into vetch stubble; NVS+s: no tillage plus in-row subsoil into vetch stubble; CT: conventional tillage; CT+s: conventional tillage plus in-row subsoil.

**VR: very rare, 10 specimens or less; R: rare 11 to 50 specimens (Rivard, 1964).

Table 34. Numbers and species of carabid predators collected in pitfall traps from no-tillage and conventional tillage field corn at Green Acres, Alachua Co., Fla., July - August, 1979.

Species	Treatment NWS	NWS+s	CT	CT+s	Tot.	%	Index**
Calosoma sayi Dejean	1	1	0	0	2	16.7	VR
Colliuris pennsylvanica (L.)	0	0	1	0	1	8.3	VR
Harpalus caliginosus Fab.	1	0	0	0	1	8.3	VR
Pasimachus sublaevis Beauv.	1	0	1	0	2	16.7	VR
Selenophorus palliatus Fab.	2	2	1	1	5	50.0	VR
Total	5	3	3	1	12		
%	41.7	25.0	25.0	8.3			

*NWS: no tillage into wheat stubble; NWS+s: no tillage plus in-row subsoil into wheat stubble; CT: conventional tillage; CT+s: conventional tillage plus in-row subsoil.

**VR: very rare, 10 specimens or less; R: rare, 11 to 50 specimens (Rivard, 1964).

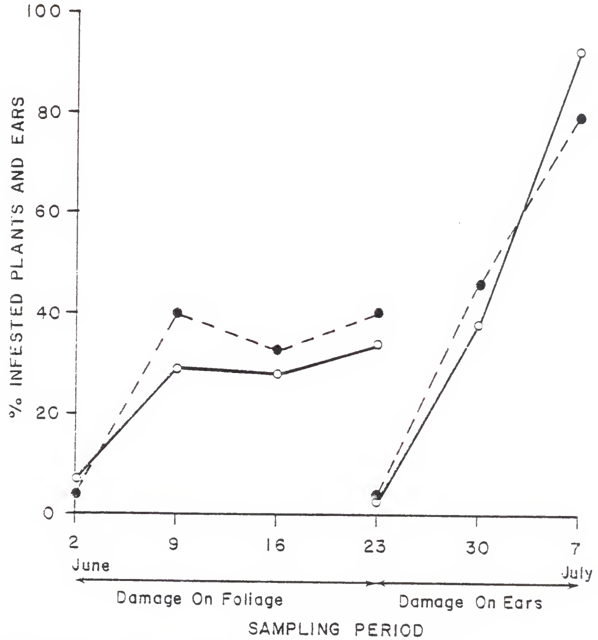


Figure 22. Weekly damage to field corn foliage and ears caused by _Spodoptera frugiperda_ and _Heliothis zea_ at Green Acres, Alachua Co., Fla., 1978.

——: no tillage into vetch stubble
----: conventional tillage

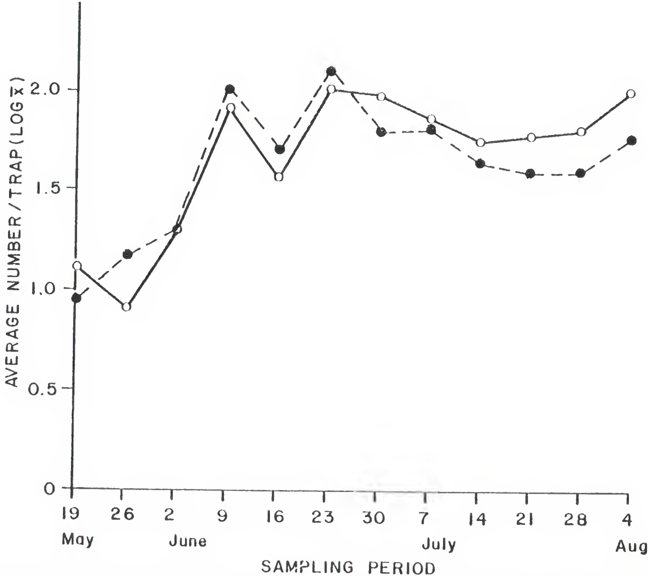


Figure 23. Weekly activity of Labidura riparia (nymphs + adults) monitored by pitfall traps (4/treat.) in field corn at Green Acres, Alachua Co., Fla., 1978.

——: no tillage into vetch stubble
----: conventional tillage

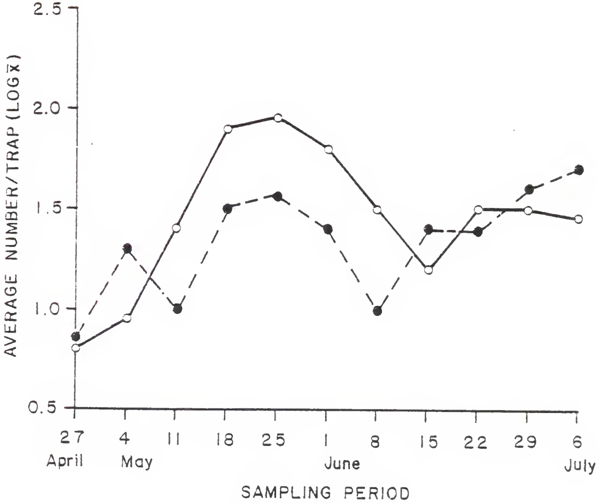


Figure 24. Weekly activity of Labidura riparia (nymphs + adults) monitored by pitfall traps (4/treat.) in field corn at Green Acres, Alachua Co., Fla., 1979.

——: no tillage into vetch stubble
----: conventional tillage

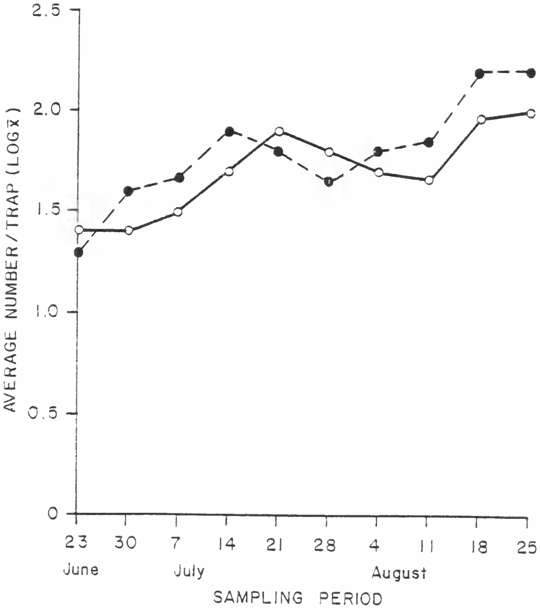


Figure 25. Weekly activity of Labidura riparia (nymphs + adults) monitored by pitfall traps (4/treat.) in field corn at Green Acres, Alachua Co., Fla., 1978.

——: no tillage into wheat stubble
----: conventional tillage

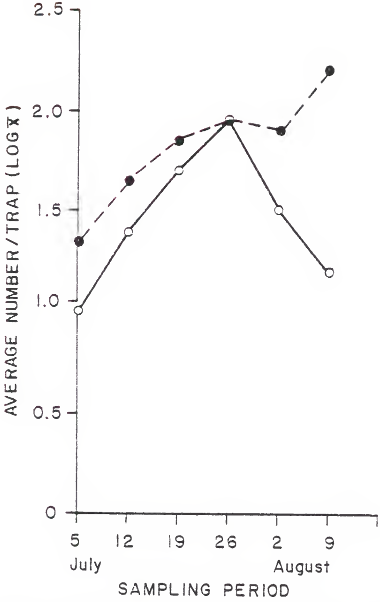


Figure 26. Weekly activity of Labidura riparia (nymphs + adults) monitored by pitfall traps (4/treat.) in field corn at Green Acres, Alachua Co., Fla., 1979.

——: no tillage into wheat stubble
----: conventional tillage

GENERAL CONCLUSIONS

Soybean Crop Systems

According to their population levels, four insects, S. festinus, P. includens, N. viridula and A. gemmatilis, were the most important above-ground pests observed during the two years. Populations of these insects, as well as injury levels caused did not differ significantly in soybeans grown in no-tillage and conventional tillage systems. However, if serious infestations of E. lignosellus are to be avoided, cultural practices must include applications of a good soil insecticide, early planting and irrigation.

Corn Crop Systems

Infestations due to S. frugiperda and H. zea, the most important above-ground pests observed on corn, were more severe in late planted than in early planted field corn, but were not affected by the tillage methods. These pests are not, according to the results, expected to cause more damage in no-tillage corn than in conventionally tilled corn.

Wireworm populations were not affected by the no-tillage practice. Although no tillage greatly increased cutworm populations, no apparent damage was done to corn by these insects. However, cutworms may be expected to cause more

damage to nontilled corn than to the conventional tillage corn. Therefore, a good program for weed control and insecticidal treatment of the soil must be considered as an important part of the cropping procedure when no tillage is adopted for corn production. No tillage reduced lesser cornstalk borer damage to corn seedlings. This practice may be used in an integrated control program along with early planting, irrigation and applications of a soil insecticide in order to regulate Elasmopalpus infestations in corn.

Arthropod Predators

No-tillage crop production did not affect ground spider populations in either corn or soybean systems. Numbers of spiders were very low when populations of most pests appeared or were high. The striped earwig, L. riparia, was the most abundant species collected in pitfall traps. The effect of no tillage on the earwig was not consistent.

Fifteen species of carabid beetles belonging to eleven genera were collected from both crop systems. However, in numbers, none of the species exceeded the Rivard's 'rare' category. In soybean systems the majority of carabids were collected from no-till plots. Whereas, in corn systems most carabids were recorded from conventional tillage treatments.

Corn and Soybean Yields

Corn yields recorded from no-tillage systems were statistically equal to those from the conventional tillage

(see Appendix C). Herbicide costs and fuel consumption, in this case, determine net money returns from the no-tillage farming. If (no cost/benefit analysis was done) herbicide costs exceeded the saving from reduced fuel consumption, no-tillage resulted in decreased benefits in this study.

No-tillage farming resulted in lower yields in soybean crop systems (see Appendix D). Inadequate weed control was believed to be the reason for lower yields recorded from the no tillage. These results confirmed that good weed control is a prerequisite to acceptable crop yields from no-tillage systems.

APPENDIX A

CHEMICAL NAMES OF HERBICIDES MENTIONED OR USED IN THE EXPERIMENTS

Common name	Chemical name
Alachlor	2-chloro-2',6'-diethyl-N-(methoxy-methyl)-acetanilide
Atrazine	2-chloro-4-(ethylamino)-6-(isopro-pylamino)-s-triazine
Linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea
Metribuzin	4-amino-6-tert-butyl-3-(methylthio)-as-triazine-5 (4H) one
Paraquat	(1,1'-dimethyl-4,4'-bipyridinium ion)
Simazine	2-chloro-4,6-bis (ethylamino)-s-triazine
2,4-D	(2,4-dichlorophenoxy) acetic acid

APPENDIX B

PREDATORY ACTIVITY OF *LABIDURA* ON *ANTICARSIA* IMMATURES

The effectiveness of *L. riparia* as a predator on *A. gemmatilis* immatures was assessed in the laboratory by introducing one *Labidura* male into a cottage cheese cup containing 5 or 15 *Anticarsia* larvae. Some cups (with larvae and *Labidura*) were placed on a table for direct observations. Others were kept in a growth chamber (temperature 28° C) for 24 hours. Predation on pupae was studied by placing three pupae into each cup; the pupae were covered with 1 cm of sand. One male *Labidura* was introduced into each cup and the cups were kept in the growth chamber.

Direct observations indicated that small and medium larvae (1-2.0 cm) were more easily caught and killed than larger (over 2 cm) larvae. Large larvae were punctured after a few minutes of struggle, but were not generally consumed. *Labidura* were observed to kill five small larvae within two minutes without completely consuming any or consumed only one. An average of 5.2 minutes were required to consume a small larva. These observations agreed with an earlier conclusion by Bishara (1934, cited by Price and Shepard, 1977) that *L. riparia* may kill more prey than it consumes.

Observations made after 24 hours also showed the effectiveness of L. riparia as a predator of Anticarsia immatures:

VBC* size	No. Labidura Tested	No. VBC Exposed	No.VBC Killed	No. VBC Consumed Totally	Partially
Small (1-1.5 cm	9	71	64	32	6
Medium (1.6-2 cm)	8	46	40	8	15
Large (over 2 cm)	13	45	32	2	21

*VBC: Velvetbean caterpillar (A. gemmatilis).

Averages calculated from the table above indicated that one Labidura male killed (24 hours) 7.1, 5.0 and 2.4 small, medium and large larvae, respectively, but consumed (totally) only 3.5, 1.0 and 0.1 small, medium and large larvae. The data also showed that the number of larvae killed or consumed by a single Labidura decreased as the age of the larvae increased. Hassanein et al. (1968) came to the same conclusion when they exposed larvae of Prodenia litura Fab. to L. riparia.

Thirty-two pupae were exposed to 11 Labidura for 24 hours. A total of 12 pupae were consumed. The earwig opened (usually longitudinally) the pupal case of the prey and consumed the contents. Each Labidura thus consumed an average of 1.1 pupae.

The impact of L. riparia on A. gemmatilis larval populations may be tremendous and important in regulating these populations in the field. The earwig kills many more prey than it consumes and is generally observed in large numbers in the

fields. This impact, however, is believed to be less than what was observed in confinement. Velvetbean caterpillars wriggle vigorously and drop from the plant when disturbed. Such a behavior prevents a predator from easily catching the larvae. Moreover, *L. riparia* feeds on a variety of prey and would "prefer" to prey on those small arthropods it can easily kill.

APPENDIX C

YIELD OF "DEKALB XL 78 A" CORN FROM GREEN ACRES

To estimate the yield, corn ears were collected from all the plants in two center rows (6.10 m long) of each replication in the vetch stubble experiment. In the wheat stubble experiment, all the plants in the two rows were collected, and the yield was estimated as dry matter (but not as grain). The yield of corn recorded from the vetch stubble experiment is shown below (yield reported at 15.5% moisture):

Treatment	Avg. Yield (kg/ha)*		
	1978	1979	Total
No tillage into vetch stubble	3031	5932	4472
No tillage plus in-row subsoil	2887	5932	4409
Conventional tillage	2464	3107	2785
Conventional tillage plus in-row subsoil	2668	3562	3115

*In the analysis of variance, no significant differences were detected between the means. Therefore Duncan's comparisons were not made.

The analysis of data revealed no significant differences between treatments for yield either in 1978 or 1979.

Corn yields (dry matter) from the wheat stubble experiment are shown in the table below (yield reported at 15.5% moisture):

Treatment	Avg. Yield (kg/ha)* 1978	1979	Total
No tillage into wheat stubble	5034	7253	6143
No tillage plus in-row subsoil	4892	7854	6373
Conventional tillage	5395	6053	5724
Conventional tillage plus in-row subsoil	5080	6844	5962

*In the analysis of variance, no significant differences were detected between the means. Therefore, Duncan's comparisons were not made.

No tillage and conventional tillage produced 6143 and 5724 kg/ha (average of two years), respectively, but these means were not statistically different.

The no-tillage practice did not significantly affect yields of corn seeded in either the vetch or wheat stubble. Since yields of corn were statistically the same in the two tillage systems, the cost of herbicides and saving in fuel consumption will determine net money returns. Because if, for equal yields, costs of herbicides (used in no tillage) exceed the saving due to reduced machinery use, no-tillage farming will result in reduced net benefits. Other factors such as soil protection against erosion, possibility of two crops per year or per season when no tillage is used, may also be considered when making the decision to adopt the no-tillage farming.

APPENDIX D

AVERAGE YIELDS OF "COBB" SOYBEANS

Yield estimates were made at Green Acres in 1978 and 1979. Pods were harvested from two center rows (6.10 m long) in each replication (four replications per treatment). The yield, shown below, is reported at 13% moisture:

Treatment	Avg. Yield (kg/ha)		
	1978	1979	Total
No tillage into oat stubble	1937*	975a**	1456a
No tillage plus in-row subsoil	1746	1379b	1563a
Conventional tillage	2304	1749b	2027b
Conventional tillage plus in-row subsoil	2009	1614b	1812b

*In the analysis of variance for 1978 data, no significant differences were detected between the means. Therefore, Duncan's comparisons were not made.

**Values not followed by the same letter in each column are significantly different at the 0.05 level by Duncan's new multiple range test.

In 1978, conventional tillage and no-tillage soybeans produced respectively 2304 and 1937 kg/ha. The statistical analysis failed to detect any significant differences between treatments. In the 1979 season, however, soybean yields were significantly (P=0.05) lower in the no tillage into oat stubble than in the conventional tillage. The two-year average yields also were lower in the no tillage than in the conventional tillage.

Higher lesser cornstalk borer damage to soybean seedlings in the no tillage was not believed to be the reason

for lower yields in the no tillage. It is believed that reduced yields recorded from the no tillage were due to inadequate weed control, especially the bahiagrass (Paspalum notatum Flugge) which has colonized those plots that were not tilled for three successive years. Several workers (Triplett and Lytle, 1972; Griffith et al., 1973) recorded lower crop yields from no-tillage systems when weed control was not adequate. Although no cost/benefit analysis was done, it is believed that this yield reduction resulted in reduced net money returns.

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BIOGRAPHICAL SKETCH

Ki-Munseki Lema was born on August 7, 1945, in Luvanga (Kivulu), Bas-Zaire, a few miles away from Kinshasa, capital of Zaire. He pursued his secondary education at and was graduated with honors from the "Ecole Technique Secondaire d'Agriculture" (Gombe-Matadi), in June 1967. In December, 1967, he entered the "Université Officielle du Congo," now known as "Université Nationale du Zaire, Campus de Lubumbashi," and obtained the diploma of "Candidat en Sciences Agronomiques." In November, 1969, he entered the "Université Lovanium" at Kinshasa (now Université Nationale du Zaire, Campus de Kinshasa) and received the degree of "Ingénieur Agronome des Régions Tropicales," with distinction, in June, 1972. Thereafter he joined the faculty of agriculture at Kinshasa where he worked from 1972 to 1973 as Assistant Lecturer in Entomology.

In July, 1973, he was selected as a possible candidate for a Rockefeller Foundation fellowship, and was sent to Ibadan, Nigeria, for an intensive couse in English, after which he entered the University of Florida and was awarded a Rockefeller Foundation fellowship to pursue graduate studies in entomology. He obtained the degree of Master of Science in December, 1976, and the fellowship was extended for the Ph.D. program in January, 1977.

The author is a member of the Florida Entomological Society and the Entomological Society of America.

He is married to the former Lugwadio mi-Konde. They are the parents of a wonderful four-year-old daughter, Lukamba Nsunda, and a "troublesome" two-year-old son, Kapela.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Reece I. Sailer, Chairman
Professor of Entomology
and Nematology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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